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DETAILED PROJECT REPORT. SMALL BEACH EROSION CONTROL PROJECT. B--ETC(U)
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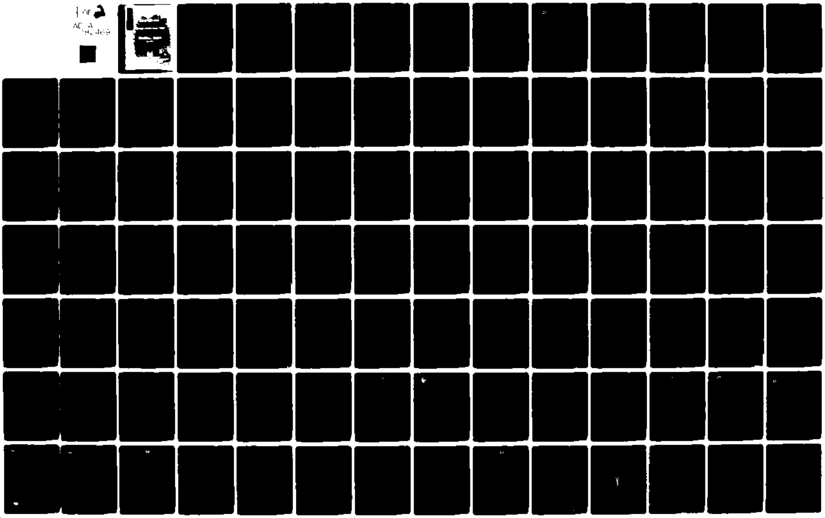

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REPORT DOCUMENTATION PAGE

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Broadkill Beach, Delaware
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Littoral materials
Shorelines

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this report is to present the results of a study made to determine the economic and engineering feasibility of restoring and stabilizing a portion of the shoreline of Broadkill Beach by providing beach erosion control measures that would result in a recreational beach adequate to meet the present add future needs of the area.

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The District Engineer finds that erosion is occuring along the shoreline in Broadkill Beach and that the best way of correcting the situation is by the placement of initial beachfill, sand fence, and periodic beach nourishment.

It has been determined that the costs of providing beach erosion control measure at Broadkill Beach are justified by the benefits in prospect, and that Federal participation in the first cost and periodic nourishment is warranted to the full extent permitted under existing law.

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DETAILED PROJECT REPORT

SMALL BEACH EROSION CONTROL PROJECT,

BROADKILL BEACH, DELAWARE

SYLLABUS

The purpose of this report is to present the results of a study made to determine the economic and engineering feasibility of restoring and stabilizing a portion of the shoreline of Broadkill Beach by providing beach erosion control measures that would result in a recreational beach adequate to meet the present and future needs of the area.

The District Engineer finds that erosion is occurring along the shoreline of Broadkill Beach and that the best way of correcting the situation is by the placement of initial beachfill, sand fence, and periodic beach nourishment.

It has been determined that the costs of providing beach erosion control measures at Broadkill Beach are justified by the benefits in prospect, and that Federal participation in the first cost and periodic nourishment is warranted to the full extent permitted under existing law.

The District Engineer recommends, subject to certain conditions of local cooperation, adoption of a project authorizing Federal participation in the cost of restoring and stabilizing 4,500 feet of the shore at Broadkill Beach. The Federal share of the estimated first cost of constructing the improvement would be $56,100. The Federal share of the estimated cost for periodic nourishment of the beach would be $5,380 annually for a period of 10 years. All costs are stated at July 1971 price levels.

DETAILED PROJECT REPORT
SMALL BEACH EROSION CONTROL PROJECT
BROADKILL BEACH, DELAWARE

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DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
CUSTOM HOUSE—2D & CHESTNUT STREETS
PHILADELPHIA, PENNSYLVANIA 19106

IN REPLY REFER TO
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SUBJECT: Detailed Project Report - Small Beach Erosion Control Project - Broadkill Beach, Delaware

Division Engineer, North Atlantic

AUTHORITY

1. This detailed project report is submitted in accordance with the procedures prescribed for the small beach erosion control project authority provided by Section 103 of the River and Harbor Act of 1962, as amended by Section 310 of the River and Harbor Act of 1965 to read as follows:

"The Secretary of the Army is hereby authorized to undertake construction of small shore and beach restoration and protection projects not specifically authorized by Congress, which otherwise comply with section 1 of this Act, when he finds that such work is advisable, and he is further authorized to allot from any appropriations hereafter made for civil works, not to exceed $25,000,000 for any one fiscal year for the Federal share of the costs of construction of such projects: Provided, That not more than $1,000,000 shall be allotted for this purpose for any single project and the total amount allotted shall be sufficient to complete the Federal participation in the project under this section including periodic nourishment as provided for under section 1(c) of this Act: Provided further, That the provisions of local cooperation specified in section 1 of this Act shall apply: And provided further, That the work shall be complete in itself and shall not commit the United States to any additional improvements to insure its successful operation, except for participation in periodic beach nourishment in accordance with section 1(c) of this Act, and as may result from the normal procedure applying to projects authorized after submission of survey reports."

Mr. Ernest A. Davidson, Director, Delaware State Highway Department, in his letter of 2 August 1966, requested that a study be made in accordance with this law and with a view to providing a project that would protect the shoreline at Broadkill Beach, Delaware from further erosion. Authority to prepare this report is contained in the Division Engineer's letter, NADPL-F, dated 16 January 1967, to the Chief of Engineers, subject: "Reconnaissance Report on Prospective Section 103 Project - Broadkill Beach, Delaware".

PURPOSE AND EXTENT OF STUDY

2. The purpose of the investigation was to determine the economic and engineering feasibility of protecting the shoreline of Broadkill Beach by providing beach erosion control measures that would result in a recreational beach adequate to satisfy the present and future needs of the area.

3. Engineering investigations conducted specifically for the problem area included studies to determine the following: the effect of littoral forces; the characteristics and source of the littoral materials; the extent of shoreline and offshore changes; and the effects of existing structures. Field investigations included soil borings and beach surveys including profiles. Office studies included analysis of costs and benefits of the considered plan of improvement.

PRIOR REPORTS

4. A beach erosion control report, covering the area from Kitts Hummock to Fenwick Island, made on a cooperative basis with the State of Delaware, was submitted to Congress by the Secretary of the Army on 14 July 1957, and printed in House Document No. 216, 85th Congress, 1st Session. The report concluded that improvements to all areas except the area from Rehoboth Beach to Indian River Inlet were not economically justified. The latest report is one on a study concerning beach erosion control and hurricane protection along the Delaware shores from Pickering Beach to Fenwick Island. That report was printed in Senate Document No. 90, 90th Congress, 2nd Session. It contained recommendations for improvements along the shorefront from Cape Henlopen to Fenwick Island. In addition, there are several other reports on pertinent navigation, beach erosion control and hurricane protection studies. All prior reports are summarized in table 1.

DESCRIPTION

5. The summer resort of Broadkill Beach is located in Sussex County on Delaware Bay about three miles northwest of Lewes, Delaware, as shown on plate 1. It consists of about 150 houses, predominantly summer cottages, and extends along approximately 6,000 feet of bay frontage. About 95 houses are located in the proximity of the beach and 55 houses are on the west side of the road that runs parallel to the shoreline. The beach was approximately 60 feet wide in 1967 at the high water line, fronting a dune which was about 30 feet wide at the base and having a top elevation between 10 and 12 feet above mean low water.

TABLE 1
PRIOR REPORTS

Year	Publication	Date of Authorizing Act	Subject or Recommendation
1872	H. Ex. Doc. 60, 42d Cong., 2d Sess.	3 Mar 1873	The report provides a 6-ft. deep channel in Broadkill River from Delaware Bay to Milton, Delaware.
1906	H. Doc. 214, 59th Cong., 2d Sess.	2 Mar 1907	Modifications to mouth of Broadkill River, including construction of jetty on the north side of Broadkill Inlet.
1953	Not printed	26 June 1953	The portion of the project which provides for an entrance channel from Delaware Bay to Broadkill River as abandoned.
1957	H. Doc. 216, 85th Cong., 1st Sess.	3 July 1958	Federal participation in cost of restoration and subsequent periodic nourishment, not to exceed 10 years, of shore from Rehoboth Beach to Indian River Inlet, Delaware.
1963	Report dated Aug. 1963, from North Atlantic Division to Chief of Engineers, entitled: "After-Action Report on Operation Five-High"	--	This report contains pertinent information on storm damages, and emergency shore rehabilitation work along the coasts of N. Y., N. J., Del., Md. and Va. after the storm of 6-8 Mar. 1962, as provided for under P. L. 875, 81st Cong.
1964	H. Doc. 348, 88th Cong., 2d Sess.	--	Unfavorable. Improvements for protection from hurricane tidal flooding in Delaware River and Bay, Pa., N. J. and Delaware not be undertaken by the United States at that time.
1966	Report dated December 1966 from District Engineer to Division Engineer, entitled: "Reconnaisance Report - Small Beach Erosion Control Project - Broadkill Beach, Del."		A detailed investigation be undertaken for providing improvements at Broadkill Beach, Delaware.
1968	S. Doc. 90, 90th Cong., 2d Sess.	13 Aug 1968	Federal participation in the cost of combined beach erosion control and hurricane protection including the placement of periodic nourishment as required for the shore from Cape Henlopen to the Delaware-Maryland line.

6. The permanent population at Broadkill Beach in 1965 was estimated to be 35. During the summer months, the population in Broadkill Beach is increased considerably by the influx of summer residents and vacationists. For example, in 1965 the summer population was estimated to be 550. The estimate of summer population does not include one - and two-day visitors, but only those who spend from several days to the entire summer. These additional 515 people are those, therefore, who own cottages in the area or rent accommodations during the summer months. The distribution of population considered as tributary for beach use is presented in table 2. The table lists the areas included and the percentage considered tributary. The tributary area is the entire State of Delaware, portions of the States of Maryland and New Jersey, and portions of Washington, D. C. and Philadelphia, Pennsylvania. The total tributary population is approximately 52,000.

TABLE 2

TRIBUTARY POPULATION
(1960 Census)

	Total Population	Percent Tributary	Tributary Population
State of Delaware	446,292	5.0	22,314
Baltimore, Md. Urbanized Area	1,418,948	0.75	10,641
Annapolis, Md.	23,385	0.75	175
Washington, D. C. Urbanized Area	1,808,423	0.75	13,563
Caroline County, Md.	19,462	0.75	146
Cecil County, Md.	48,408	0.75	363
Kent County, Md.	15,481	0.75	116
Queen Annes County, Md.	16,569	0.75	124
Philadelphia, Pa. Urbanized Area	3,635,228	0.1	3,635
Cape May County, N. J.	48,555	0.5	243
Salem County, N. J.	58,711	0.5	293
TOTAL	7,539,462		51,613
		SAY	52,000

7. The area around Broadkill Beach is served by first-class highways, viz., U.S. Route 113, which runs north and south about 14 miles west of Broadkill Beach, and State Route 14, which runs north and south paralleling Delaware Bay about 4 miles inland from Broadkill Beach. These highways provide access to Broadkill Beach from northern points such as Wilmington, Philadelphia and New York, and from distant points to the south via route 13 and the Chesapeake Bay Bridge-Tunnel. Another bridge, the Chesapeake Bay Bridge, provides access to Broadkill Beach from points to the west such as Annapolis, Baltimore, and Washington.

8. At the present, existing on street parking is available and adequate in the study area. As the demand for such facilities increases sufficient additional area could be developed along access roads to accommodate any future increase in attendance.

9. The length of the shoreline at Broadkill Beach is approximately 6,000 feet. This total length is 100 percent privately owned.

10. The estimated present fair market values of the shorefront property (excluding beach area) and of the entire community are listed in table 3. Those values are based on a gross estimate made by this office in connection with this study.

TABLE 3

ESTIMATED PROPERTY VALUES IN BROADKILL BEACH
(July 1971)

Beach Front Property* Present Fair Value	Entire Community Present Fair Value
$	$
1,221,000	2,866,000

*Excluding beach area.

11. The water entering Delaware Bay from Delaware River is polluted, but the degree of pollution drops off sharply in the bay. Neither the State nor County health authorities prohibit the use of the bay for water contact recreation in the study area. The State of Delaware Water and Air Resources Commission (presently under the Department of Natural Resources and Environmental Control) does not anticipate any large scale impairment of recreational use of beaches along the Delaware Bay due to pollution. However, the Commission believes that there are and will continue to be isolated cases of pollution in the immediate bayshore areas at certain points. The Delaware River Basin Commission has established minimum water quality standards for the Delaware River and Bay. In the study area, those standards require that the waters be maintained in a safe and satisfactory condition for the following uses: (a) industrial water supply after reasonable treatment; (b) wildlife, maintenance and propagation of resident fish, shellfish and other aquatic life, and passage of an anadromous fish; (c) recreation; and (d) navigation. At the present time, the waters in the study area meet the necessary requirements for recreational use. However, to insure that they are maintained at a suitable level of quality, many treatment plants are being planned on a local and regional level which will provide treatment ranging from high intermediate to tertiary.

STATEMENT OF THE PROBLEM AND IMPROVEMENTS DESIRED

12. The problem at Broadkill Beach is beach erosion along Delaware Bay caused by wave action during storms. As a result of this erosion, much recreational beach has been lost, and shore properties are now susceptible to damage from extreme storm tides and wave action.

13. A public hearing was held on 11 September 1963 at Rehoboth Beach, Delaware, to establish the needs and views of local interests regarding shore protection and improvements along the Delaware Coast. Representatives from Federal, State, and local governments, and officials of commercial and civilian organizations, and interested individuals attended the hearing. Local interests desire corrective measures to combat beach erosion permanently along the entire Delaware Coast through a program of restoration and maintenance of beaches for recreational and protective purposes, and stabilization of the shoreline. They believe that the improvements are justified because of the increasing value of beaches and resort communities as recreational and summer residential areas.

GEOMORPHOLOGY

14. Broadkill Beach lies within the Coastal Plain province, which extends seaward to the edge of the continental shelf and westward to the gentle slopes of the Piedmont province. The submerged portion of the Coastal Plain province has a southeastward slope of 5 to 6 feet per mile and extends seaward approximately 65 miles to the edge of the continental shelf. The channel of Delaware River is traceable for approximately 50 miles across the shelf. The prominent features of the shoreline are barrier beaches fronting low dunes and separated from firm ground by marshes and bays. A detailed discussion of the geomorphology of the Delaware shoreline is contained in appendix A.

LITTORAL MATERIALS

15. A detailed discussion of the physical characteristics, composition, and sources of the littoral material along Delaware Bay is contained in appendix B. A general summary of the characteristics of littoral materials for Delaware Bay is contained in the following paragraphs.

a. The median diameter represents the midpoint in a range of grain size diameters contained in a sample. Analysis of the 1954, 1964 and 1969 samples, which were taken above mean high water, shows fine to medium sands. The 1954 sample data indicated medium sand at mid-tide level along the entire Delaware Bay shore, while the 1964 and 1969 samples show medium to coarse sand at Broadkill Beach. Analysis of both the 1954 and 1964 nearshore samples showed fine to medium sands. A small amount of silt was found in the offshore samples. Samples of the nearshore and offshore bottoms were not obtained in 1969.

b. The coefficient of sorting expresses the degree of sorting of the material in a sample. It is a measure of the spread of grain sizes of the material. If there were perfect sorting, the value of the coefficient of sorting would be unity. There was relatively little change in sorting characteristics in the beach samples and nearshore samples. The average and individual coefficient of sorting values determined for the Delaware Bay shore samples indicate poorly sorted beach materials.

c. The skewness is a function of the symmetry of the grain size distribution in a sample. It indicates on which side of the median diameter, and how far from it, the point of maximum sorting lies. The point of maximum sorting coincides with the median diameter when skewness is unity. Data on skewness coefficients for the survey samples indicate that the point of maximum sorting tends to occur on the fine side of the median diameter.

16. Although there are natural sources supplying littoral material to the beaches, the supply is inadequate to prevent, with a few exceptions, a general recession of the Delaware shoreline. Analysis of Cape May and Cape Henlopen beach materials indicates that little, if any, material from the New Jersey beaches crosses Delaware Bay to feed Broadkill Beach. The only other possible sources of littoral materials are the inland areas, the Delaware River watershed and the adjacent beaches and banks. The first two sources have been discounted because the sediments, chiefly silt, that are carried by streams are deposited in the marshes and lagoons lying behind the beaches, and those that are carried by Delaware River are trapped in the shoaling areas of Delaware Bay. It is concluded therefore that the natural sources are the beaches and banks of the adjacent shores.

LITTORAL FORCES

17. WAVES. No statistical data of wave height or direction are available for the study area. Visual observations indicate that almost three-quarters of the offshore waves approach Broadkill Beach from the northeast and east.

18. CURRENTS. Drift-float observations made in the vicinity of the Delaware Breakwaters (plate 1) indicate that the tidal currents are generally parallel to the inner breakwater on both ebb and flood flows, but that currents near the tip of Cape Henlopen turn and move westward from the Cape and the outer breakwater during flood flows. In Delaware Bay off Broadkill Beach, normal maximum flood and ebb tidal currents are approximately three feet per second toward the northwest and southeast, respectively.

19. WINDS. Wind data are available from observations by the U. S. Weather Bureau at Delaware Breakwater, Delaware, for the years 1924 through 1941, a period of 18 years. Wind roses presenting these data are shown on plate 2. The Breakwater wind data show that the prevailing wind direction is southwest, although winds from other directions are nearly as frequent. The data also show that gale force winds -- those over 30 miles per hour -- come most often from the northwest and that winds of more than 60 miles per hour originated from seven of the eight principal compass directions.

20. STORMS. Hurricanes are the most severe storms which affect the Atlantic Coast. Paths of selected storms of hurricane intensity are shown on plate 2. In addition to hurricanes, there are also "northeasters" -- storms characterized by strong northeasterly winds -- which affect the study area and cause extensive damage. Tide and wind data associated with significant storms of record are presented in table 4.

a. The hurricane of August 1933 moved inland south of the study area and produced strong onshore winds with velocities of 75 miles per hour, as estimated by the Weather Bureau, at Delaware Breakwater. Heavy rain accompanied this storm, which caused flooding in most areas, however, residential damage was comparatively minor.

b. The hurricane of September 1944, which passed about 50 miles to the east of the Delaware coast, caused extensive damage. Gravel streets were washed out, and sand was deposited on streets and properties adjacent to the beach.

c. Eight other hurricanes produced relatively slight damage within the study area. The hurricane of September 1938 passed the Delaware Coast about 75 miles offshore near the predicted time of low tide and therefore caused only minor damage in the study area. Hurricanes "Carol, "Edna", and "Hazel", in August, September and October 1954, respectively, caused considerable loss of life and tremendous property damage in the northeast United States, but only minor damage within the study area. Hurricanes "Connie" and "Diane", in August 1955, also caused only minor damage in the study area. Hurricane "Donna", in September 1960, passed the Delaware Capes about 50 miles offshore and produced high winds and pronounced wave action, but caused only minor damage within the study area.

TABLE 4

STORM DATA

Date	Storm Name	Type of Storm	Maximum Wind Atlantic City Direction	Maximum Wind Atlantic City Velocity 1/ (mph)	Highest Tide Atlantic City (feet above sld)	Highest Tide Breakwater (feet above sld)
Aug 1933		Tropical	E	76	5.0	6.1
Nov 1935		Extra-Tropical	NE	66	5.3	-
Sep 1936		Tropical	NE	90	4.7	-
Sep 1938		Tropical	W	72	4.1	-
Sep 1944		Tropical	NE	91 (G)	7.6	-
			N	82 (V)		
Nov 1950		Extra-Tropical	E	72	7.0	7.2
Oct 1953		Extra-Tropical	N	29	6.1	6.0
Nov 1953		Extra-Tropical	NE	69 (G); 65 (V)	5.0	5.4
Aug 1954	Carol	Tropical	NE	57	4.4	3.7
Sep 1954	Edna	Tropical	NE	65	4.6	-
Oct 1954	Hazel	Tropical	SE	80 (G)	4.6	4.6
			SE	66		
Aug 1955	Connie	Tropical	S	65	4.0	4.5
Aug 1955	Diane	Tropical	SW	49	3.6	4.1
Oct 1955		Tropical	E	60	5.0	5.1
Sep 1956	Flossy	Tropical	E	54	4.9	5.6
Sep 1960	Donna	Tropical	WNW	83 (G)	6.1	5.2
Mar 1962		Extra-Tropical	E	58 (G)	7.2	7.9
Oct 1964	Flossy	Tropical	NE	30	4.0	4.0

1/ Generally fastest mile or highest one-minute value. (G) denotes gust and (V) five-minute value.

21. Storms from the eastern quadrants, expecially those from the northeast, have nearly unlimited fetch and cause extensive damage to the study area, especially to the beach. The most notable of these storms are discussed below.

a. The storm of November 1950 produced strong easterly winds and high tidal stages, and caused damage to highways and cottages and loss of beach.

b. The storm of November 1953 produced winds of 60 miles per hour and a tide stage 5.4 feet above sea level datum at Fort Miles, Delaware. Damage in the study area was minor to properties and beach.

c. The storm of January 1956 resulted in high water levels and caused some damage to residential property and loss of beach.

d. The storm of March 1962 was unusually severe with strong northeast winds which pushed the ocean waters on-shore for three days during five successive high tides. High tide at Breakwater, Delaware reached 7.9 feet above sea level datum or 9.9 feet above mean low water. The waves reached heights of 20 to 30 feet. Barrier dunes, beaches, shore installations, and commercial, residential, and public properties suffered extensive storm damage. The uninterrupted wind, wave and tide action raised tide levels in the inland bay areas to heights never before recorded. Damage in Broadkill Beach was estimated to be $450,000 as a result of this storm.

22. ICE. During severe winters large ice floes are found in Delaware Bay, to the extent that 15 ice piers were constructed in 1901 by the United States in the bay near Outer Breakwater, as part of the Harbor of Refuge project. Some damage from ice floes has been experienced along the Delaware Bay shore, but very little has occurred in the last three decades. The west and northwest winds which prevail during the winter months aid in preventing damage by ice to the Delaware Bay shore by forcing ice floes toward the New Jersey shore.

23. TIDES. Tides in the study area are semi-diurnal and have a mean range of 4.1 feet. The highest storm tide of record at Delaware Breakwater was 7.9 feet above sea level datum in March 1962, and the next highest occurred during the storm of November 1950 when a tide level of 7.2 feet above sea level datum was reported.

SHORE HISTORY

24. SHORELINE CHANGES. In the Broadkill Beach area, shoreline changes have been materially influenced by jetty construction. In 1843, Lewes River and Broadkill River joined near the site of the present Broadkill jetty. (See plate 1 for location). From this juncture, waters flowed northward through Broadkill Sound (formally known as Lewes Sound), parallel to the shore of Delaware Bay, for approximately 3,500 feet before emptying into the bay. The narrow finger of land thus formed between Broadkill River and the shore of Delaware Bay extended steadily northward until the construction of the Broadkill jetty was accomplished. Early reports made in connection with recommended improvements of this river indicate that the northward growth of this finger of land amounted to 120 feet per year between 1842 and 1880, and nearly 100 feet per year between 1880 and 1905. The construction of the Broadkill Inlet jetty in 1908 cut off Broadkill Sound with no direct access to Delaware Bay. This series of events accounts in part for the protruding shore upon which the community of Broadkill Beach is now located. During the storm of 6-8 March 1962, a new inlet to Broadkill Sound was opened (between profile lines 26 and 27) at a location approximately 1,000 feet upcoast of the old entrance. Aerial photos taken immediately after the March 1962 storm show the inlet cutting through to Broadkill Sound at right angles to the shore. Aerial photos taken two years later show that the bayward end of the inlet had migrated downcoast approximately 400 feet so that the original northeast-southwest alignment has shifted to an east-west alignment. Between 1964 and 1968 the beach closed naturally.

25. In 1917-1918 Lewes River between Lewes and Broadkill River was dredged by the Federal government to form part of the Inland Waterway between Rehoboth Bay and Delaware Bay, with Broadkill Inlet forming the Delaware Bay entrance. Broadkill Inlet subsequently proved to be inadequate for the needs of the area, and excessive shoaling made maintenance costs high. In 1937, Roosevelt Inlet was constructed west of Lewes; thus the waters of the Broadkill were encouraged to flow southeastward to the Bay through the Lewes River. This diversion increased the shoaling of Broadkill Inlet until today the littoral drift and wind-blown sands have closed the inlet entirely. The locations of the high water shoreline changes at Broadkill Beach, including the effects of beachfill placed by the State of Delaware between 1957 and 1962, are shown on plate 3. Table 5 lists the net natural shoreline changes by eliminating the effects of previous beachfill and derives the net loss for Broadkill Beach. Based on adjusted mean high waterline surveys over a 121 year period the shoreline recession rate for Broadkill Beach is estimated at an average net loss of 3 feet per year.

TABLE 5

SHORELINE CHANGES ALONG BROADKILL BEACH

Profile No. (1964 Survey)	Net Change in Location of Mean High Water (Feet and Feet per Year)							
	1843 to 1884 (41 yrs.)		1884 to 1954 (70 yrs.)		1954 to 1964 (10 yrs.)		1843 to 1964 (121 yrs.)	
	Ft.	Ft/Yr.	Ft.	Ft/Yr.	Ft.	Ft/Yr.	Ft.	Ft/Yr.
24	-250	-6	-225	-3	-30	-3	-505	-4
25	-1400	-34	+900	+13	-356	-36	-856	-7
26	+700	+17	-350	-5	-176	-18	+174	+1
27	+1300	+32	-475	-7	-210	-21	+615	+5

Net area change between profiles 24 and 27 over 121 years = -32,700 ft^2/yr
Length = 12,000 ft. Change = <u>-2.72 ft/yr</u>

Net area change in project area (profiles 25 and 26 only)
over 121 years = -16,300 ft^2/yr
Length = 4,500 ft. Change = <u>-3.62 ft/yr</u>

Utilizing above estimates shoreline change rounded to <u>-3 ft/yr</u>

26. OFFSHORE DEPTHS. A hydrographic survey of the Delaware Bay area by the Corps of Engineers in 1931 was based upon range lines too widely spaced to permit plotting of nearshore contours for purpose of comparison. However, data from that survey were used to furnish additional information regarding movement of contours further offshore. Surveys made in connection with design and improvement of jetties and entrance channels were also used in the study of movement of offshore depth contours.

27. In Delaware Bay, mud flats and silt overburden exist along much of the shoreline, and offshore profiles are exceedingly flat. Under these conditions, it is possible that a single storm could erode one-half foot of silt and cause offshore depth contours to move several hundred feet landward. Contours near the existing and former outlets of several streams exhibit delta-like formations. Random shifting of the contours in the bay is a natural effect of

the combination of flat slopes and silt and mud overburden. Shoals well out in the bay have migrated slowly, advancing and retreating with no apparent consistent trend. Near shore, the 6-foot depth contour has undergone a net movement landward between 1843 and 1969 along most of the Delaware Bay section. This movement has also been inconsistent.

28. At Broadkill Beach the 6-foot depth contour was nearly 7,000 feet offshore in 1884. By 1931 this contour had assumed a position roughly parallel to the shore but only 1,000 feet offshore. The 1954, 1964 and 1969 surveys indicate little change in location of this contour since 1931.

29. Contours southeast of Broadkill Beach (profiles 26 to 28) indicate random shifting since 1843. In general, the 6-, 12-, and 18-foot contours moved landward between 1843 and 1884, and seaward between 1884 and 1926. This seaward movement subsequently reversed, and the Corps of Engineers' soundings of 1931 indicate that these contours have moved landward since 1926. By 1954 all of the 6-foot contours had shifted to positions landward of their 1843, 1926, and 1931 locations. Between 1954 and 1969, the 6-foot depth contour location remained relatively unchanged. The net change since 1843 has been a landward recession of this contour along the entire section of beach (profile lines 26 to 28). These changes in the offshore depths since 1843 are shown on plate 3.

30. PRIOR CORRECTIVE ACTION AND EXISTING STRUCTURES. Shore protection measures along the shores of Delaware have been taken by the State, by the Delaware River and Bay Authority, and by private interests. The Federal government has provided navigation improvements which, in some cases, have affected adjacent shorelines. Beach fill at Broadkill Beach was placed by the State of Delaware in accordance with the Corps' recommendations in House Document No. 216, Beach Erosion Control Study -- Delaware Coast from Kitts Hummock to Fenwick Island, but without Federal participation in the cost.

31. Prior to 1956 no overall plan for shore protection along the Delaware shores was considered. However, various sizes and types of groins were constructed by the State to stabilize the shoreline at Broadkill Beach. Table 6 gives the location, type of construction, dimensions, date of construction and present condition of the major structures at Broadkill Beach. Descriptions of the measures taken for protection of the shore against erosion within Broadkill Beach are presented in the following paragraphs.

32. The major groin system at Broadkill Beach consists of five timber groins constructed between 1950 and 1954. These groins range from 186 to 199 feet in length with a top width of 16 inches. The elevations of the shore ends are 11.0 to 12.0 feet above mean low

water and the outer ends are one foot above mean low water. Effective beach protection at the south end of Broadkill Beach was provided by the three groins constructed in 1950, but erosion became a problem to the north. Two additional groins, one with a timber crib forming the center section, were built in 1954 north of the original three. The five groins are in good condition. However, erosion is being experienced along the shore just north of the last groin. Abnormal tides and storm wave action have caused erosion in back of the inner end of the northernmost groin. The State placed 76,800 cubic yards of beach fill along 1,500 feet of beach in 1957, an additional 120,000 cubic yards of material in 1961 and 180,000 cubic yards of material in 1962 of which 143,000 cubic yards was placed hydraulically. Since that time, the State of Delaware has periodically repaired dune damage by dumping broken concrete and topping it with sand and gravel, but records of the amounts were not noted. In 1969, dunes along half of the study area were so repaired. The State has also dumped broken concrete to form permeable groin-like structures at Alabama Avenue and Georgia Avenue. However, all of that work is considered to be of a temporary nature.

33. Broadkill River and the inlet area have been under improvement by the Federal government since Congress adopted a project in 1873 with subsequent modifications. During 1907 and 1908 a new mouth was dredged in order to establish a permanent entrance, and a pile and stone jetty was constructed on the north side of this channel to fix the inlet channel and check the northward migration of the inlet. The jetty was 1,263 feet long, with 250 feet extending from the high water line into the bay and the remainder curving southward across the barrier beach and into Broadkill Sound. Shoaling and accretion gradually built up the southern point of the entrance until the inlet closed. In June 1953, Congress authorized the abandonment of that part of the project which provided for an entrance channel from Delaware Bay at this location. The jetty is still visible, but nearly covered with sand, and a wide beach was formed north and south of it. Access to the river is presently via Lewes and Rehoboth Canal and Roosevelt Inlet.

34. PROFILES. Eight profiles were surveyed in 1964 along Broadkill Beach and four of those lines were partially surveyed again in 1969. A 1954 survey included six profiles in the same general area. The profiles usually extend normal to the shoreline from the first street paralleling the shoreline or a point 100 to 300 feet inland from the high water line, a maximum distance of one mile for the longer range lines, and a minimum distance of 1/4-mile for the shorter range lines. These measurements show the slopes of the present beach and near shore bottom in considerable detail, and when compared with previous measurements, permit a determination of the changes in slope and contour which have occured.

TABLE 6

BROADKILL BEACH, DELAWARE - EXISTING MAJOR PROTECTIVE STRUCTURES

Type of Structure	Location Referenced to Local 1/ features or survey lines	Type of Construction	Top Elevation (M.L.W.) (approximate) Inner end	Outer end	Length (feet)	Year Built	Condition	Owner
	Broadkill Beach							
Groin	3210 ft. north of line 26	Timber & Stone	12	1	195	1954	good	State
Groin	2750 ft. north of line 26	Timber	12	1	186	1954	good	State
Groin	2290 ft. north of line 26	Timber	11	1	196	1950	good	State
Groin	1810 ft. north of line 26	Timber	11	1	196	1950	good	State
Groin	1320 ft. north of line 26	Timber	11	1	199	1950	good	State
	Old Broadkill Inlet							
Jetty	2800 ft. south of line 27	Timber & Stone	8	8	1263	1908	poor	U.S. Govt.

1/ Referenced line and location of structure shown on plate 5.

35. The surveys prior to 1954 did not include any detailed data on the area above low water, so it is not feasible to compare the present slopes with any prior to 1954. The earlier surveys, however, extended considerable distances offshore and comparison of those surveys with the 1954 and 1964 surveys reveals that the areas offshore have undergone relatively little net gradient change since the 1842-43 survey. The 1969 survey lines did not extend far enough offshore to make such a comparison. The offshore slopes generally average 1 on 500. Depths for distances up to a half-mile from shore are frequently less than 4 feet below mean low water. Comparison of the 1954 and 1969 profile slopes shows that erosion has caused generally steeper foreshore slopes. The existing foreshore slopes in many areas are generally 1 on 10 as compared to the average of 1 on 20 that existed in 1954. Profiles of the four lines surveyed in 1969 and the plots of those lines as surveyed in 1954 and 1964 are shown on plate 4 for comparative purposes.

36. VOLUMETRIC ACCRETION AND EROSION. The volumetric changes for the periods 1931-1954, 1954-1969 were determined by direct comparison of profile data and computation by the average end area method. Since earlier surveys were generally of limited scope, only broad generalizations can be made regarding the volumetric changes between 1843 and 1931. Survey data indicate that erosion occurred along Delaware Bay above the mean low water level while deposition occurred below mean low water, with the net annual change above and below mean low water being erosion during the period 1954 to 1969. Comparisons of surveys performed over a long period of time provide the only accurate means of determining the volumetric change occurring along a shore. A knowledge of these changes and corresponding rates of change provides a basis for determining the amount of material required to maintain or to stabilize the beach. But only broad generalizations are possible, because the data from early surveys are limited in scope. Comparative profiles plotted from beach elevations and offshore soundings were used to reflect the volume changes. Most of the volume changes are based upon surveys of 1843, 1931, 1954, 1964 and 1969. Table 7 shows volumetric changes which occurred at Broadkill Beach. The table presents estimates of the average annual rate of change per foot of shoreline based on profiles developed from past surveys and adjusted for any placement of beachfill made in the period shown. During the period 1954 to 1969, Broadkill Beach experienced excessive net erosion above and below the mean low water level. This is attributed to the devastating effect of the March 1962 storm.

TABLE 7

VOLUMETRIC ACCRETION AND EROSION FOR VARIOUS PERIODS BROADKILL BEACH, DELAWARE
(total change above & below MLW)

Average Annual Rate of Change
(cubic yards per foot of shore per year)

1843-1954 (111 years)	1954-1969 (15 years)	1843-1969 (126 years)
-1.5	-7.0	-2.2

ANALYSIS OF THE PROBLEM

37. SHORE PROCESSES. The Delaware Bay area, except for Cape Henlopen, has a history of erosion over the period of record. The Cape section has experienced accretion primarily due to the northerly drift along the Atlantic coast line, with some contributions coming from the Delaware Bay shore. Accretions at the southeast side of groins at Slaughter Beach and Broadkill Beach, and at the west side of the jetty at Roosevelt Inlet indicate that a nodal zone exists between Broadkill Beach and Roosevelt Inlet. The location of the nodal zone is not fixed, but varies with changing conditions of tides, winds and waves. The report on the beach erosion control study printed in House Document No. 216, 85th Congress, 1st Session, indicates the nodal area to be above Broadkill Beach as evidenced by accretions on the northwest sides of the groins at Broadkill Beach at the time of that study. It now appears that Broadkill Beach is in the nodal area. However, the area sometimes has a predominate movement of material in one direction and then in the other. Northwest of the nodal zone the littoral movement is to the northwest, and southeast of that zone the littoral movement is southeast toward the ocean.

38. Along the Delaware Bay shore of Delaware, where tidal marshes are fronted by narrow beaches and where there are no promontories, it is believed that the source of supply for accreting beaches is an eroding beach elsewhere. It is very difficult to formulate an estimate of the average volume of littoral drift. One such estimate was made during the study mentioned in the preceeding paragraph when it was determined that accumulations at Roosevelt Inlet, four miles southeast of Broadkill Beach, were 11,000 cubic yards, annually. Estimates based on accumulations between 1954 and 1964 indicate an apparent rate of drift at this inlet of 7,400 cubic yards per year. The present erosion problem is considered to be the result of wave action and cyclic movement rather than of continuous erosion.

39. If no remedial measures are taken it can be expected that the shoreline recession will continue at its present rate, the beach destruction will continue and damage and loss of upland property will occur along the study area.

40. METHODS OF CORRECTING THE PROBLEM. As stated in paragraph 13, local interests desire restoration, stabilization and maintenance of the beaches and shoreline for protective and recreational purposes. Analyses of the causes of erosion were made and the methods of correcting the problem considered were construction of groins and bulkheads, placement of beachfill with periodic nourishment and erection of sand fencing to entrap and retain windborne sand. The analyses provided data on the expected extent of protection provided by these methods and the cost for each.

41. BEACH FILL DESIGN CRITERIA. The two highest tides of record in the study area occurred during the storms of November 1950 and March 1962, when tides rose to 9.2 and 9.9 feet, respectively, above mean low water. A berm height of 10 feet above mean low water and a minimum width of 50 feet are considered to be the minimum desirable to protect the development from erosion which might occur from a severe storm. The estimated beach slope is 1 on 10, which generally conforms to the existing slope above mean low water. These dimensions have been selected as design dimensions because they have proved adequate for dissipating wave energy and protecting existing developments at other beaches along the Delaware Coast. These dimensions should protect against all but the most extreme storm conditions. Sand fence placed along the fill would encourage additional accretion of material on the existing dunes. In order to maintain the beach at the design conditions, it would be necessary to provide periodic nourishment. This would be accomplished by direct placement of material where required. Until some experience with a project at the study area is obtained, an estimate of the quantity of material required to maintain the project dimensions must be based on past erosion rates. The annual loss in the study area for the periods 1843 to 1954, 1954 to 1969 and 1843 to 1969 were 6,750 cubic yards, 31,500 cubic yards and 9,900 cubic yards, respectively. However, the losses for the periods 1954 to 1969 were materially affected by the severe storm of March 1962. Although the storm surge, which resulted from that storm, is not a particularly rare occurrence, the length of time during which the storm attacked the shore in the study area was rare. Consequently, the rate of erosion was particularly severe and not representative of normal conditions. The period 1843 to 1969, because of its length, was considered the most suitable period for determining the periodic nourishment rate, which is estimated to be 10,000 cubic yards per year. If the existing groin field were maintained and extended to Alabama Avenue, it is expected that the periodic nourishment rate would be reduced to 6,700 cubic yards per year.

42. Samples of materials from the shore and offshore areas were obtained during surveys conducted in the period August to October 1954, June to August 1964 and September 1969. The results of analyses of these samples are discussed in appendix B, LITTORAL MATERIALS. The materials for beach fill and nourishment should have size and sorting characteristics similar to those which are native to the particular beach under consideration. In order to determine the size and sorting characteristics for an individual beach, offshore and beach samples were used to determine cumulative size distribution curves by methods outlined in CERC Technical Memorandum No. 102. The basis for selecting suitable fill materials was direct comparison of existing beach and borrow area samples. Tables B-1 and B-3 in appendix B present the geometric mean diameters (GM), the geometric standard deviation (GDS), median diameter (M), coefficient of sorting (S_o) and log of skewness (log S_k) for samples taken in 1964 and 1969 along the study area.

PLAN OF PROTECTION

43. The plan of improvement considered most suitable for Broadkill Beach consists of improving 4,500 feet of beach, extending from a point 2,700 feet north of the access road (Route 16) to a point 1,800 feet south of that road by: placement of approximately 110,000 cubic yards of suitable sand to provide a berm 50 feet wide at an elevation 10 feet above mean low water with a beach slope of 1 on 10, erection of 4,500 feet of sand fence for preservation of the berm and periodic nourishment of the beach by artificial placement of approximately 40,000 cubic yards of suitable sand every four years. Suitable material for initial fill and periodic nourishment is available from offshore borrow sources. A typical section of the beach fill is shown on plate 5.

ESTIMATE OF FIRST COST

44. The first cost of constructing the proposed improvements is estimated to be $243,000. This estimate, based on price levels of July 1971, includes allowances for contingencies, supervision and administration, and engineering and design. The estimate was derived as discussed in the following paragraphs and the items comprising it are summarized in table 8. Appendix C presents details of the estimate.

TABLE 8

ESTIMATE OF FIRST COST

1.	Place 110,000 c.y. @ $1.71/c.y.	$187,916
2.	Erect 4,500 l.f. sand fence @ $1.20/l.f.	5,400
3.	Contingency @ 15%	28,997
4.	Engineering and design	14,479
5.	Supervision and administration	5,973
	Total Estimated First Cost 1/	$242,765
	Rounded	$243,000

1/ Exclusive of preauthorization study costs of $25,300.

ESTIMATE OF ANNUAL CHARGES

45. Annual charges consist of interest and amortization on the first cost of the proposed plan of improvement, annual maintenance costs of the sand fence and the annual cost of periodic nourishment of the beach. Interest and amortization charges were computed at the rate of 5-3/8 percent and based on an economic life of 50 years. Since the proposed improvements can be constructed in less than one year, no charge for interest during construction was included. The annual charge for periodic nourishment was based on an estimated nourishment of 40,000 cubic yards every 4 years at a cost of $2.01 per cubic yard and includes costs of contingencies, engineering and design, and supervision and administration. The estimated annual charges (determined in appendix C) arising from the items of work under the proposed plan of improvement are $39,200.

ESTIMATES OF BENEFITS

46. GENERAL. The benefits that could accrue as a result of the construction of the proposed project include recreation, property enhancement, prevention of erosion damage, prevention of storm damage, decrease in the maintenance of existing structures, and preservation of fresh water marshes. These benefits are described in the following paragraphs.

47. RECREATIONAL BENEFITS. Estimated recreational benefits are based on the stabilization of a beach which if not improved and maintained, will be useless for public bathing by 1987 due to the present retreat of the shoreline. Estimates of recreational use of the beach were obtained from local interests for the study area and compared with the tributary population and available housing facilities to determine the estimated peak load on the beach.

48. The resort season in the study area extends from mid-June to Labor Day, averaging 82 days. Allowing 20 percent or 16 days for inclement weather, about 66 days are available each summer for recreational use of the beach. Of these days, 22 are weekend peak days and 44 are weekdays. The average daily attendance is estimated to be one-third of the peak day attendance. The average weekday beach attendance and the peak-day attendance at Broadkill Beach in 1964 were 300 and 900 people, respectively, or a total of 33,000 (300 x 44 + 900 x 22).

49. Future participation in swimming activities is expected to increase substantially. The Bureau of Outdoor Recreation (BOR) predicts an increase in the national rate of swimming activities at 3.26 percent annually between 1960 and 2000. For the same period, the BOR predicts that a 1.63 percent increase per year in population is expected nationwide. Therefore, the annual rate of increase in swimming per capita nationwide would be 1.6 percent (1.0326/1.0163). That increase will be stimulated by increases in leisure time and personal income. The North Atlantic Regional Water Resources Study (NAR) has showed that an annual increase of 1.23 percent in population is expected in the study area between 1970 and 2020. The annual rate of increase in swimming activities in the study area would be 2.85 percent (1.016 x 1.0123). Based on those projections, it is expected that beach attendance at Broadkill Beach will increase to 173,000 persons by 2023.

50. While the demand for beaches is continuing to increase, it can be expected that the beach area available at Broadkill Beach will continue to decrease as a result of erosion. Comparison of surveys made in the study area show the shoreline to be receding at an average rate of three feet per year. The average width of beach in 1967 was 60 feet. Therefore, it can be expected that the shoreline will have receded to the building line by 1987. As a result, beach area suitable for recreational purposes will be negligible. Figure 1 shows the projected beach use and beach capacity by year for the study area. Without beach improvements, it is projected that there will be sufficient beach area to handle the peak day and average day attendance until 1982 and 1985, respectively. With the improvement under consideration, there would be sufficient area to accommodate the demand until 2023.

51. There is free and easy access to Broadkill Beach but the basic facilities for safety and comfort are minimal. Therefore, it was estimated that users of the beach would be willing to pay an average value of $0.50 per person for 75 square feet. At that value, the average annual recreational benefits, for a project beginning in 1973 and discounted at 5-3/8 percent, would be $22,800.

52. LAND ENHANCEMENT. Enhancement benefits attributable to a project are the increased direct primary benefits from use of land for an economically higher state of development than would occur in the absence of the project. Although an increase in beach attendance is expected, commercialization of the area or any other higher type of use cannot be envisioned. A realistic appraisal indicates that the community would remain as a resort for individual property owners and would only attract additional individuals to establish summer cottages as a result of the protection and beach improvement. Therefore, no enhancement benefits would be applicable. The tax records of Sussex County indicated that many individuals own property along the shorefront with no individual or firm owning any large tract of land. In view of the above, it is believed that no windfall benefits would accrue to any individual or municipality due to the provisions of the project.

53. PREVENTION OF EROSION DAMAGE. The beach in the study area has a history of erosion. The project will restore the beach to its former dimensions and maintain it, thereby protecting existing shore structures and upland property. Comparison of hydrographic surveys of the Delaware Bay coastline of Delaware shows shoreline recession to be occurring at an average rate of 3 feet per year in the study area, making allowances for material placed artificially previously. If this erosion is allowed to continue at its present rate in the study area, it would result in the loss of the beach and damage and loss of upland property. Benefits for the prevention of erosion damage were computed on the following basis:

a. The rate of erosion was projected to and over a 50-year period and it was determined that the beach area would be completely lost after 1987, the 14th year.

b. Damages incurred through erosion between the 14th and 50th year reflect only the land, houses and utilities (minus salvage value estimated at 25% of the fair value) that are located 100 feet behind the actual beach area. The value of the damage at the 1973 level of development and July 1971 price level is estimated to be $791,300. No values were claimed for the loss of the actual beach area because this would result in a duplication of recreational benefits.

c. Studies made in the NAR study have indicated that damageable assets in flood plains in the region which the study area is located are increasing at a rate which is six-tenths the increase in personal income. Since the study area is a flood plain, it was estimated that the value of the property in the area would increase at a similar rate. That increase includes both development and increased affluence of the property owners. In the study area, personal income is projected to increase at approximately 4 percent per year. Therefore, the value of the property subject to erosion is expected to increase at 2.4 percent per year. In 1987, when the first properties will be damaged without remedial measures being undertaken, the value of the property which will be lost in the study area during the 50-year project life would be $1,102,900. The annual value of the loss in 1987 would be $30,600. Discounting those damages to 1973 values, the average annual benefit from preventing that erosion would be $18,900.

54. PREVENTION OF STORM DAMAGE. In past years the beach in the study area has been subject to severe storm damage, especially from storms in 1933, 1944, 1950, 1953, 1954 and 1962. The stage-damage curve shown on figure 2 was based on a damage survey conducted after the storm of March 1962. The stage-frequency (figure 3) and the stage-damage curves were combined to produce the damage-frequency curve shown on figure 4 which was used to estimate the average annual damages. The average annual damages at July 1971 prices and 1973 level of development would be $96,100. Provision of a suitable beach would prevent some wave and inundation damage resulting from storms. As shown on figure 4, it is estimated that the project would reduce the zero damage storm from one with 80 percent chance of occurrence in any year to one with a 25 percent chance of occurrence. Based on existing development, the average annual damage prevented by the beach fill would be $8000. However, as indicated in the previous paragraph, the damages in the study area can be expected to increase at a growth rate of 2.4 percent per year until 1987 when beach front homes are affected by erosion damage. The stage damage curve for the year 2023 shown on figure 2 is based on the assumption that the beach front homes will be completely demolished by that time. As a result of these losses due to erosion, the annual affluence growth rate between 1987 and 2023 was reduced from 2.4 percent to 0.85 percent. The average annual damages prevented both in 1973 and 2023 are shown respectively in figures 4 and 5. These values are $8,000 in 1973 and $12,200 in 2023 based on 1971 price levels. Assuming the previously discussed affluence factors and a discount rate of 5-3/8 percent, the average annual equivalent damages prevented are $9,200.

55. DECREASE IN MAINTENANCE COST OF EXISTING STRUCTURES. Restoration and stabilization of the beach would result in a decrease in the maintenance cost of five existing major groins. Based on data obtained on the present cost of maintaining shore structures, it is estimated that maintenance costs for stone groins would be reduced by $2.40 per foot per year and for timber groins by $1.20 per foot per year. The annual benefit resulting from decreased maintenance cost would be 97 linear feet of stone groin multiplied by $2.40 plus 875 linear feet of timber groin multiplied by $1.20. The sum of those calculations is equal to $1,300 (rounded).

56. PRESERVATION OF FRESHWATER MARSHES. A benefit of the proposed project which is not as obvious as others is that the dunes and beach form the eastern wall of the largest freshwater marsh impoundment in Delaware. The marshes from the Broadkill Beach road (State Road 16) to the Fowlers Beach road (State Road 38) are freshwater marshes and all are in the "intake area" for the national wildlife refuge at Prime Hook. They are most valuable being maintained as freshwater marshes. Maintenance of the adjacent beaches will help to preserve their integrity as freshwater marshes. No monetary value has been assigned to this benefit.

57. SUMMARY OF BENEFITS. A summary of the average annual benefits that would accrue due to the proposed improvements is presented in table 9.

TABLE 9

SUMMARY OF AVERAGE ANNUAL BENEFITS

	Public	Private	Total
Recreational	$22,800	-	$22,800
Land enhancement	0	0	0
Prevention of erosion damage	-	$18,900	18,900
Prevention of storm damage	-	9,200	9,200
Decrease in maintenance	1,300	-	1,300
Total	$24,100	$28,100	$52,200
Percent of total	46.2	53.8	100.0

PROJECT FORMULATION

58. GENERAL. The basic objective of project formulation is to provide the best use, or combination of uses, of water and related land resources to meet all foreseeable short and long-term needs. The most effective use of economic resources required for a project is made if they are utilized in such a way that the amount by which benefits exceed costs is a maximum. That is the net-benefit-maximization principle. An equally important concept of project formulation requires consideration of all project effects, favorable and unfavorable, tangible and intangible, including environmental, social, political and regional impacts.

59. BEACH FILL. The provisions of a beach of suitable dimensions in the study area would provide protection to the development from storms and erosion and would provide space for recreational use. In determining the minimum berm dimensions, consideration was given to seasonal fluctuations and the amount of beach which could be removed by a single storm. If the project berm were to be completely eroded during a storm, the project would no longer be effective and the development lying behind the beach would be destroyed by erosion. In order to assure such destruction would not occur, a minimum berm width of 50 feet and an elevation of 10 feet above mean low water were selected. The beach area provided by a beach with a berm 50 feet wide would provide adequate space for the projected recreational users. Consequently, the cost of providing a wider beach berm would not be commensurate with the benefits and a project berm width of 50 feet was selected. The planned elevation of the berm was selected not only to provide adequate protection but also to prevent normal wave action from overtopping the recreational beach, thereby preventing a reduction of the recreation benefits expected from the project.

60. GROINS. Groins were considered as a method of reducing the periodic nourishment rate for the project. However, they did not provide a reduction in the cost of nourishing the beach by an amount commensurate with the cost of maintaining the existing groins and constructing and maintaining two new groins which would be required to complete the groin field.

61. FEASIBILITY OF PROJECT LIMIT EXTENSION. Beach usage and development to the north and south of the project area is minimal. The beach area which would be provided by the proposed plan would be sufficient to meet the needs of the existing and projected beach demand in the Broadkill Beach area. Consequently, extension of the project in either direction would not result in any additional recreational beach benefits. Since the homes to the north and south of the proposed project area are elevated on pilings, there are no storm

damages that could be prevented by the extension of the project limits. However, extension of the project limits would provide protection from erosion damages to beachfront homes that would be affected during the project life. When the incremental benefits were compared to the incremental costs for extension of the project, it was realized that such an extension would not be economically justified. Therefore, extension of the proposed project limits is not considered to be feasible at this time.

JUSTIFICATION OF IMPROVEMENTS

62. The average annual benefits over the life of the project would be $52,200 and the average annual charges are $39,200 resulting in a benefit-cost ratio of approximately 1.3.

FEDERAL, NON-FEDERAL AND PRIVATE INTERESTS

63. The Federal interest in a shore protection project is considered to be essentially the benefit obtained by the United States as a landowner. However, there is no Federal land in the study area and therefore no benefit will result from this type of shore ownership. Non-Federal public interest is defined as (a) the benefits accruing to a State or a political subdivision thereof as landowner, and (b) the benefits accruing to the general public through public use of either public or private property or from protection of nearby public property. Benefits resulting from this type of ownership would amount to $24,100 annually. Private interest consists of benefits accruing to property in other types of ownership. Annual benefits to private property adjacent to the beachfront would consist of erosion damage prevention and storm damage prevention in the amounts of $18,900 and $9,200, respectively, for a total of $28,100. The entire shore frontage along the study area is privately owned property.

APPORTIONMENT OF COSTS

64. Apportionment of the first cost for constructing the proposed improvements was computed in accordance with Public Law 826, 84th Congress, as amended by the River and Harbor Act of 1962. Under present law, the Federal contribution toward the cost of beach erosion control projects is limited to fifty percent of the cost of providing protection for non-Federal publicly-owned shores, plus a share of the cost of protecting privately-owned shores where public benefits will result. For privately-owned shores, the fifty percent maximum allowable Federal contribution is adjusted by the ratio of public benefits to total benefits accruing from those shores as a result of the project. Therefore, the Federal share of the total first cost of construction of the proposed project is estimated to be 23.1 percent of $243,000 or $56,100 and the Federal share of the annual cost of periodic beach nourishment would be 23.1 percent of $23,300 or $5,380. Details of this apportionment are given in appendix C.

COORDINATION WITH OTHERS

65. PUBLIC PARTICIPATION. Two public meetings were held during the planning process. The first meeting was held on 11 September 1963 at Rehoboth Beach, Delaware, to establish the needs and views of local interests regarding shore protection and improvements along the Delaware Coast. A joint, late-stage public meeting was held on 6 January 1972 at Lewes, Delaware, to discuss study findings and the proposed plans of improvement for Lewes and Broadkill Beach. News releases were issued concerning the meetings and draft environmental statements were made available for each study. No major objections were raised at the late-stage meeting concerning the proposed plans. The principal points of discussion at the late-stage meeting concerning the Broadkill Beach studies were first, local interests desire to extend the project limits, and second, their disappointment at the time lapse expected between the completion of project studies and actual construction.

66. GOVERNMENT AGENCIES. Various phases of the investigation were coordinated with the U. S. Fish and Wildlife Service, the U. S. Public Health Service, the former Federal Water Pollution Control Administration, the U. S. Bureau of Outdoor Recreation, the Environmental Protection Agency, the Delaware State Water and Air Resources Commission, the Delaware State Board of Health, the Delaware Department of Health and Social Services, the Delaware Geological Survey, the Delaware Department of Highways and Transportation and the Delaware Department of Natural Resources and Environmental Control. Significant comments of these agencies are summarized in the following paragraphs. Updated comments were requested in December 1971. Copies of pertinent reports or letters received from these agencies are contained in appendix D.

a. The Fish and Wildlife Service submitted a report on the fish and wildlife aspects related to the proposed plan. That report was prepared in cooperation with the Delaware Department of Natural Resources and Environmental Control. The following recommendations were made in that report: "(1) that the dredged area not exceed a depth of 10 feet below MLW and be continuous with the seaward area of equal or greater depth; and (2) that dredging be conducted by a level, sweep-type procedure."

b. The Public Health Service submitted a letter with comments on water qualtity control with a view to protecting the shellfish resource.

c. The Federal Water Pollution Control Administration submitted a letter commenting on water quality and on the need to insure control of any pollution associated with the proposed project.

d. The Bureau of Outdoor Recreation submitted a letter favoring the proposed project and expressing the importance of the beaches in fulfilling the future recreation needs of the public provided public access is assured.

e. The Delaware State Water and Air Resources Commission submitted a letter with comments on water pollution. These comments were discussed previously in paragraph 11.

f. The Delaware Geological Survey submitted a letter requesting consideration of the possible effects of a change in sea level, and the nature and degree of land usaage, and that studies of the causes of the erosion of the shoreline of Delaware be continued. In view of the fact that the change in sea level is very gradual, it is anticipated that any change in level during the life of the project will not be significant. The nature and degree of land usage were considered. There is not provision for a continuing study of the causes of erosion of the shoreline of Delaware in the Corps of Engineer's programs. It appears to be an appropriate undertaking for the State Geologist.

LOCAL COOPERATION

67. Federal participation in the cost of economically justified projects for the protection of non-Federal publicly-owned and privately-owned property will require local authorities to comply with specific conditions of local cooperation. The details of the conditions of local cooperation are contained in the section entitled "Recommendations". The Governor of Delaware, Russell W. Peterson, was informed of the proposed plan of improvement and items of local cooperation. A copy of his reply, giving assurance of cooperation, is included in appendix D.

DISCUSSION AND CONCLUSIONS

68. Erosion is a problem prevailing along the entire coast of Delaware. As a result, public and private property is subject to damage from storm wave attack and tidal inundation. The constant erosion will soon reduce the beach capacity to a point were the supply of beach area will be inadequate to handle the demand for additional recreation facilities for the steadily increasing population. The most suitable plan to combat beach erosion at Broadkill Beach consists of widening the beach by the placement of suitable sand to provide the beach with a berm width of 50 feet at elevation 10 feet above mean low water, erecting a sand fence, and providing periodic nourishment of the beach.

69. The improvements for Broadkill Beach are economically justified with a benefit-cost ratio of 1.3 and adoption of Federal project is considered desirable. The total first cost of the proposed improvement, based on July 1971 prices, is estimated to be $243,000. The Federal share of the total first cost is 23.1 percent, or $56,100. The extent of the Federal share towards periodic beach nourishment is estimated to be $5,380 annually for a period of 10 years.

70. The U. S. Fish and Wildlife Service was requested to comment on the proposed improvement for Broadkill Beach. In their final report they recommended that the dredging be conducted by a level, sweep-type procedure and that the dredged area not exceed a depth of 10 feet below MLW and be continuous with the seaward area of equal of greater depth. Consideration was given to the seaward extension of the borrow area to a point where the natural bottom is at an equal or greater depth than the borrow area. The alternative was rejected because the costs were prohibitive. Consideration was also given to dredging with a shallow, level-type sweep which would provide the volume of fill required. Use of a shallow level-type sweep dredging operation would involve dredging to a depth of 10 feet or less below MLW which would yield principally only overburden material which is of very poor quality. Consequently, a larger surface area would be involved with its concomitant environmental effects in addition to requiring prohibitive costs.

RECOMMENDATIONS

71. The District Engineer recommends adoption of a small beach erosion control project at Broadkill Beach, consisting of widening 4,500 feet of beach by placement of suitable sand to provide a beach with a berm 50 feet wide at an elevation of 10 feet above mean low water with a beach slope of about 1 on 10 and erecting 4,500 feet of sand fence. The presently estimated total Federal first cost is $56,100 (23.1 percent of the total first cost of the project).

72. The District Engineer also recommends Federal participation for 10 years in defraying the cost of periodic nourishment for this 4,500 feet of shoreline. The estimated annual cost to the United States for periodic nourishment is $5,380.

73. The adoption of the recommended measures is subject to the conditions that local interests provide assurances that they will comply with Section 221 of PL 91-611 and, prior to construction, enter into written agreements enforceable in the courts that they will:

a. Provide without cost to the United States all lands, easements, and rights-of-way, including borrow areas, necessary for construction of the improvement;

b. Accomplish without cost to the United States all alterations and relocations of buildings, streets, storm drains, utilities and other structures made necessary by the construction except parts integral with the project structures;

c. Bear 76.9 percent of the total first cost of construction and of the annual cost of periodic nourishment for a period of ten years, the sums presently estimated to be $186,900 and $17,920 respectively, as a cash contribution, or in installments prior to commencement of pertinent work items, in accordance with construction schedules as required by the Chief of Engineers, the final apportionment of cost, subject to final adjustment based on public use and ownership of the shore at the time of construction, to be made after actual costs are determined;

d. Bear the entire cost for periodic nourishment after the initial period of ten years and maintain and repair during the economic life of the project all the works after completion in accordance with regulations prescribed by the Secretary of the Army;

e. Hold and save the United States free from damages due to construction or maintenance of the improvement.

f. Furnish written easements permitting public access and continued public use of the shore upon which the amount of Federal participation is based during the life of the project;

g. Adopt and enforce appropriate ordinances to provide for the preservation of the dunes;

h. Control water pollution to the extent necessary to safeguard the health of bathers;

i. Assume full responsibility for all project costs in excess of the Federal cost limitation of $1,000,000 including the cost of periodic nourishment; and

j. Provide without cost to the United States appropriate access and facilities, including parking and sanitation, necessary for realization of the public benefits upon which Federal participation is based.

STATEMENT OF FINDINGS

74. I have reviewed and evaluated, in light of the total public interest, documents concerning the proposed action, as well as the views of other agencies and the general public, relative to the various alternatives in accomplishing improvements for beach erosion control at Broadkill Beach, Delaware.

75. The possible consequences of these alternatives have been studied and evaluated according to engineering feasibility, environmental effects, social well-being, and economic factors including regional and national development.

76. In consideration of these factors, the following points were considered pertinent to my review and evaluation:

a. Engineering Considerations. The objective of this study was to formulate a plan for water and related land resource management and development that would best meet the present and future needs at Broadkill Beach. It was determined that the primary need in the study area was for beach erosion control and development of a recreational beach adequate to meet the foreseeable needs of the study area. The plan of improvement considered most suitable for Broadkill Beach consists of improving 4,500 feet of beach, extending from a point 2,700 feet north of the access road (Route 16) to a point 1,800 feet south of that road by: placement of approximately 110,000 cubic yards of suitable sand to provide a berm 50 feet wide at an elevation 10 feet above mean low water with a beach slope of 1 on 10, erection of 4,500 feet of sand fence for preservation of the berm and periodic nourishment of the beach by artificial placement of approximately 40,000 cubic yards of suitable sand every four years. Suitable material for initial fill and periodic nourishment is available from offshore borrow sources. Engineering consideration was given to taking no action, construction of groins to reduce periodic nourishment, extension of the project limits to provide protection to other bay front areas, seaward extension of the borrow source, dredging with a shallow, level-type sweep and truck-hauling of beachfill.

b. Environmental Considerations. The environmental factors that were considered in formulating and evaluating the plans of improvement for Broadkill Beach include recreation and water contact activities, water quality, fishery resources, wildlife, aesthetics and the effects of dredging. The improvements would improve the recreation and water contact activity potential of the given area. Agitation of bottom sediments by the dredge will cause a temporary increase in turbidity and bacterial counts in the overlying waters. Since the area to be affected is relatively small, there will be no significant affect on the

fishery resources. However, any shellfish or finfish caught in the path of the dredging would be destroyed, but through seasonal timing of the dredging operations the effects of this operation will be minimized. The deepening of the offshore shallow areas will also temporarily alter the habitat of some waterfowl. The deep dredging of the borrow area will create a pool in which the changing of waters will be inhibited. As a result this area, which is relatively small compared to the vast area of shallow waters in Delaware Bay, is expected to act as a sediment trap, and thus, with time the area is expected to return to original depths. In lieu of using an offshore borrow source truck hauling of the beachfill was considered. Seaward extension of the borrow area was considered as an alternative to allow a flushing action, thereby preventing any possible stagnation that might occur. These alternatives were rejected, principally because of economic reasons. Another alternative was dredging with a shallow, level-type sweep to reduce the depth of dredging that would be required. The alternative was rejected because the operation would yield principally only overburden material which is of very poor quality and because a larger surface area would be involved with its concomitant environmental effects. In an aesthetic sense, the project proposal would enhance the appearance of the beach by creating an even fill section without additional structures in the beach area. An environmental benefit of the proposed project is that the dunes and beach form the eastern wall of the largest freshwater impoundment in Delaware. Maintenance of the beaches will help preserve these marshes.

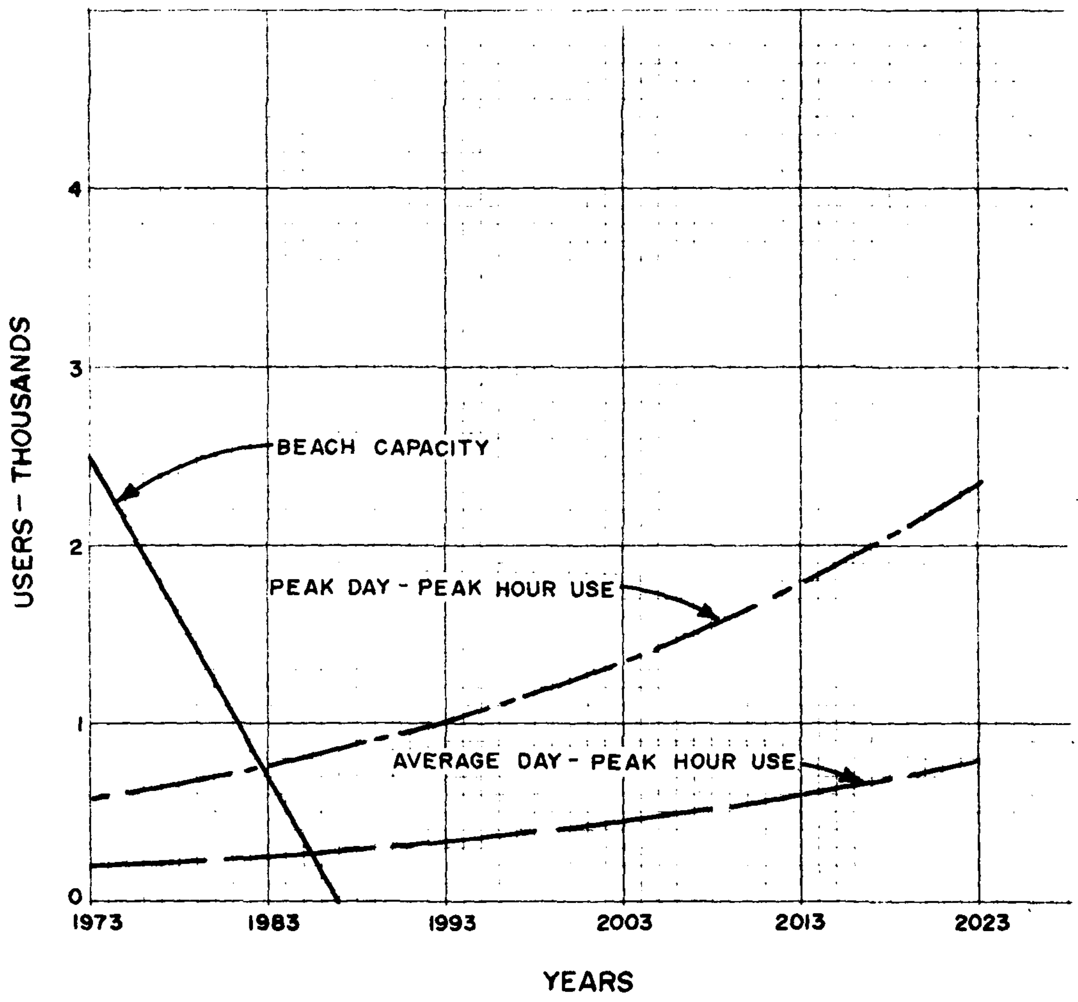
c. Economic Considerations. A balancing of economic and environmental costs and benefits has been accomplished through project formulation and in satisfying the requirements of the National Environmental Policy Act of 1969. In formulating the plan, consideration was given to all known economic influences. Consideration was also given to the desires and views of local interests. The alternative of "no action" was rejected because without remedial measures erosion would continue, recreation needs would remain unsatisfied and the desires of local interests would be ignored. Groins were rejected as an alternative because they did not provide a reduction in the cost of nourishing the beach commensurate with the cost of maintaining the existing groins and the construction and maintenance of the additional groins that would be required to complete the groin field. Seaward extension of the borrow area, and extension of the project limits were rejected as modifications to the proposed plans because the benefits accrued were not commensurate with the increase in costs. The economic benefits that would accrue as a result of the construction of the proposed plan of improvement include recreation, property enhancement, prevention of erosion damage, prevention of storm damage, and decrease in the maintenance of existing structures.

d. <u>Social Considerations</u>. The proposed plan of improvement would result in direct benefits that would increase the general welfare and security of the residents of the study area. There would be no displacement of individuals or industry through construction of the proposed project. In fact, construction of the project will improve the appearance of a presently unsightly beach resulting in an increase in its attractiveness for water-related recreation. The "no-action" alternative would have the effect of increasing the damages due to erosion and storms and reducing recreational potential.

77. I find that the action, as proposed in my recommendations, is based on thorough analysis and evaluation of various practicable alternative courses of action for achieving the stated objectives; that wherever adverse effects are found to be involved, they cannot be avoided by following reasonable alternatives which will achieve the specified purposes of the recommendation; that the recommended action is consonant with national policy, statutes, and administrative directives; that where the proposed action has an adverse effect, this effect is either ameliorated or substantially outweighed by other considerations of national policy; and that on balance the total public interest should best be served by its implementation.

CARROLL D. STRIDER
Colonel, Corps of Engineers
District Engineer

Date: February 1972

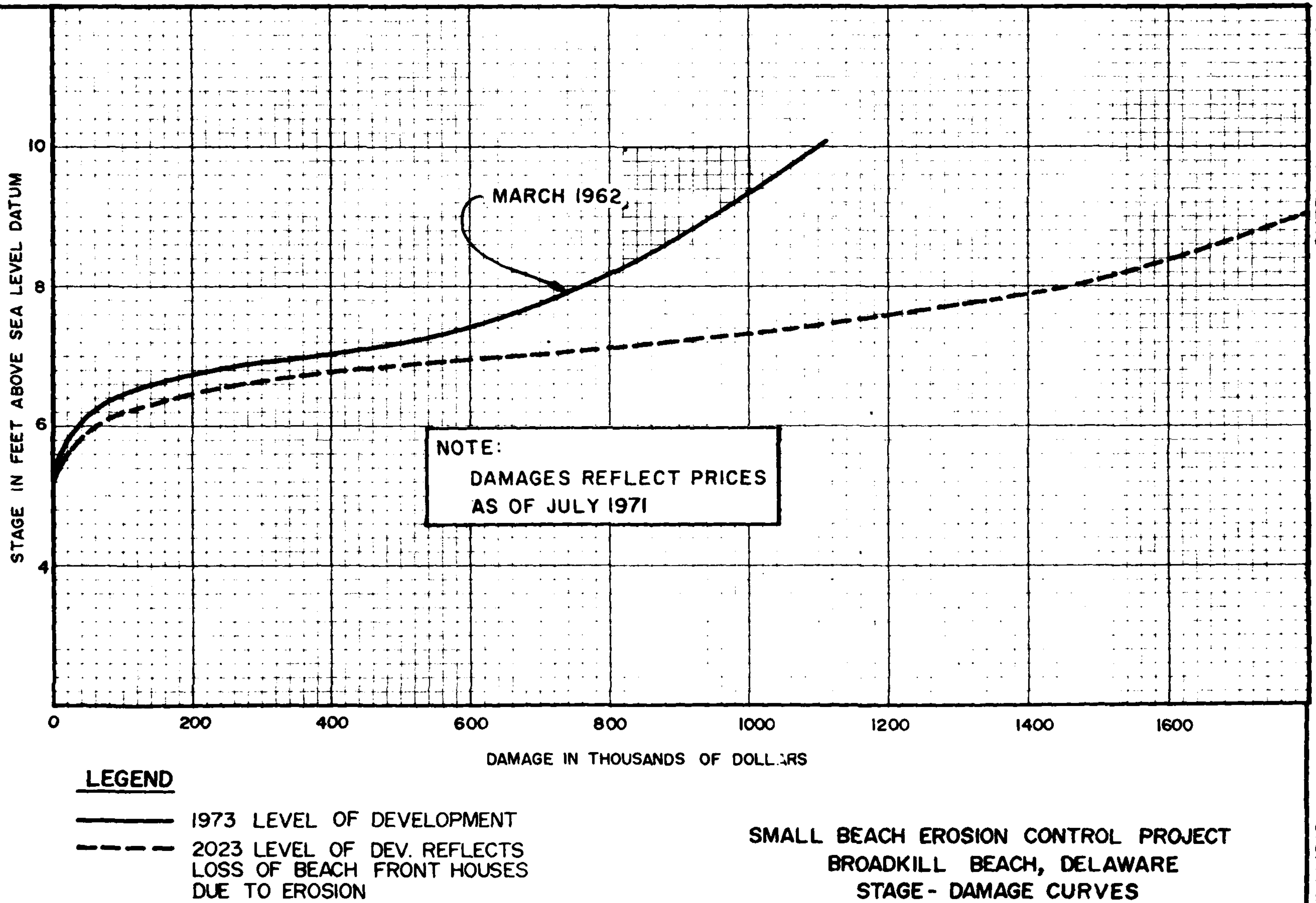


SMALL BEACH EROSION CONTROL PROJECT
BROADKILL BEACH, DELAWARE
BEACH USE AND CAPACITY

FIGURE 1

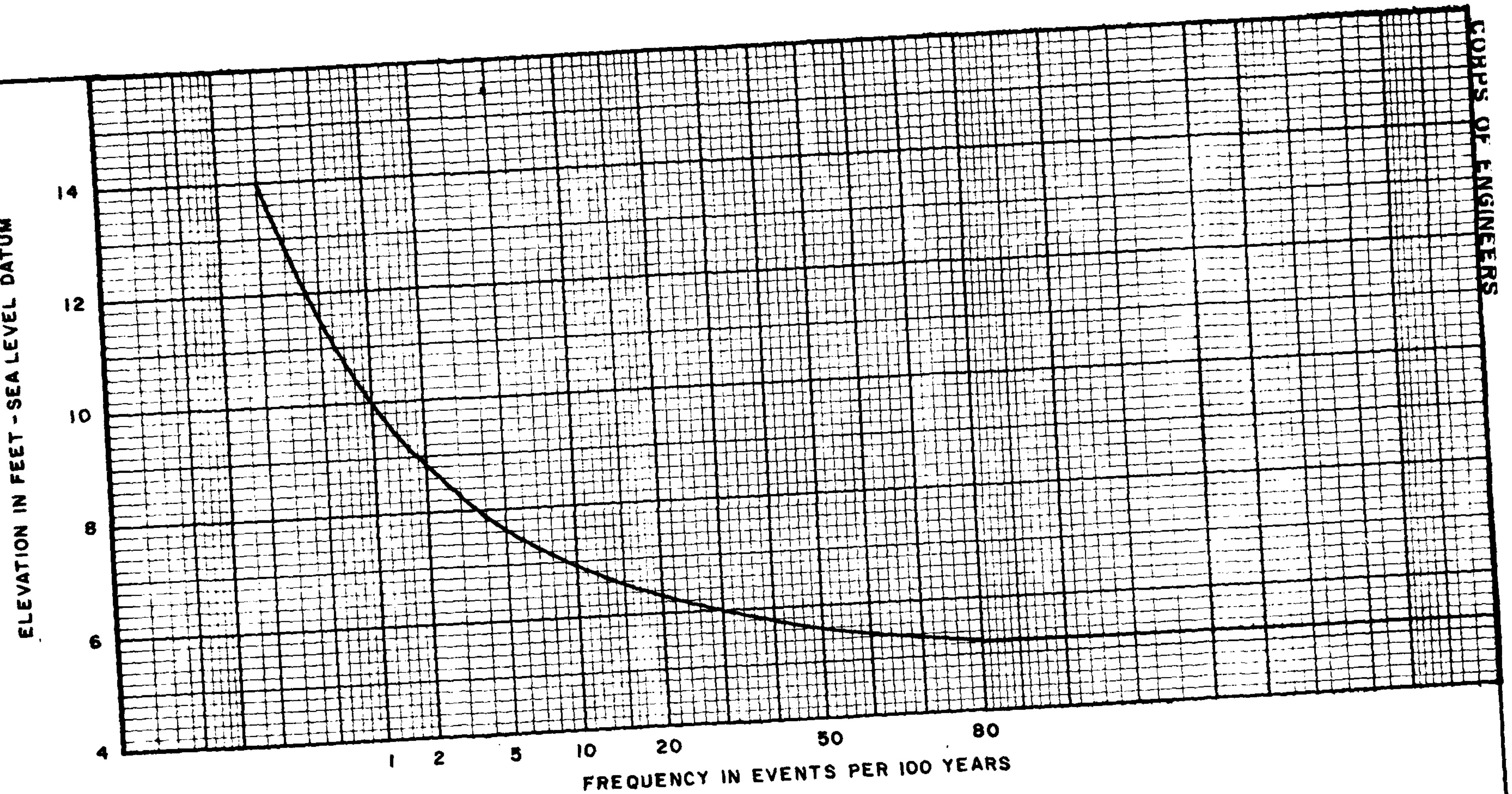
CORPS OF ENGINEERS

U.S. ARMY



SMALL BEACH EROSION CONTROL PROJECT
BROADKILL BEACH, DELAWARE
STAGE - DAMAGE CURVES

FIGURE 2



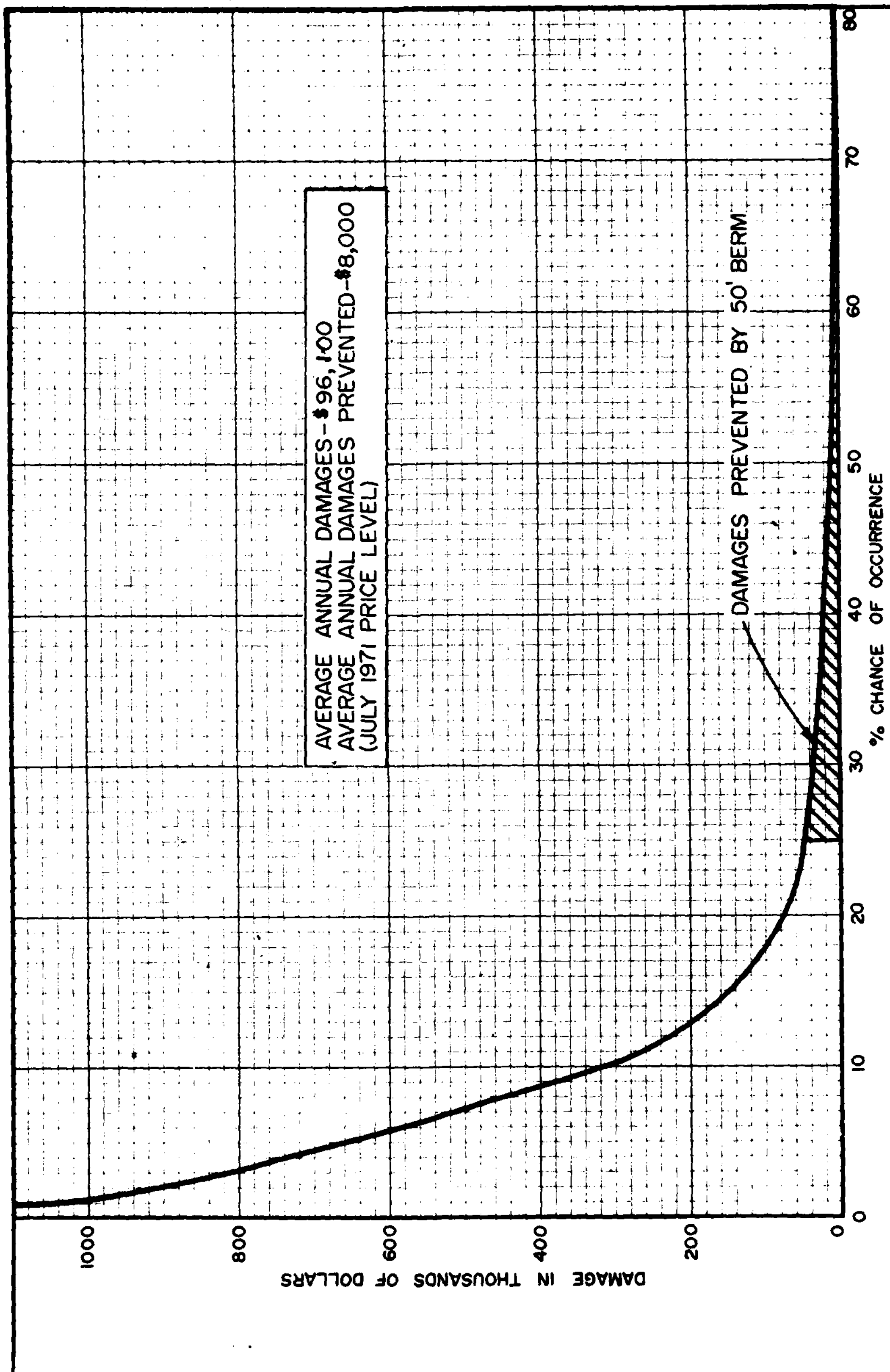
SMALL BEACH EROSION CONTROL PROJECT
BROADKILL BEACH, DELAWARE
STAGE-FREQUENCY CURVE

U.S. ARMY

FIGURE 3

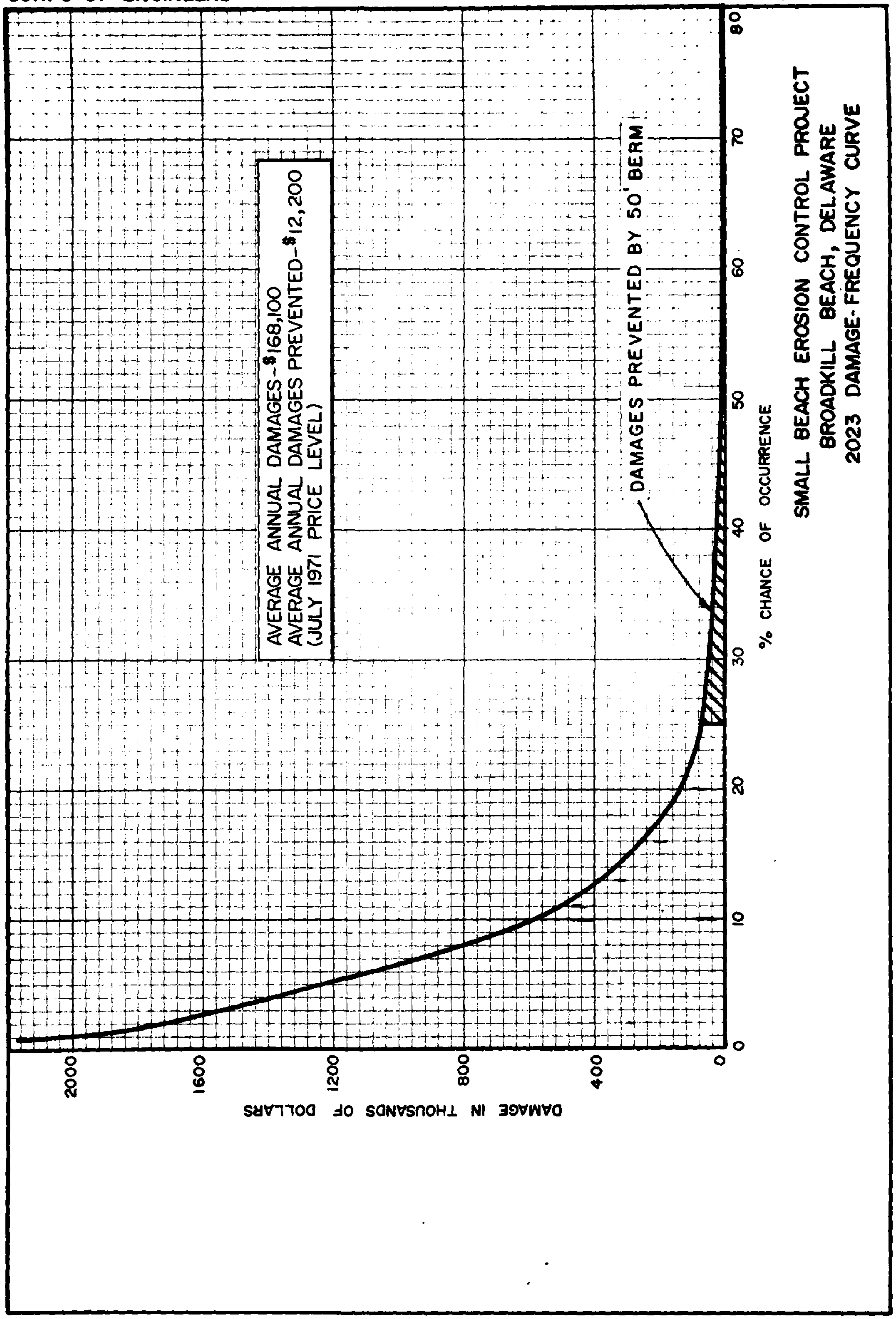
CORPS OF ENGINEERS

U.S. ARMY



SMALL BEACH EROSION CONTROL PROJECT
BROADKILL BEACH, DELAWARE
1973 DAMAGE- FREQUENCY CURVE

FIGURE 4



SMALL BEACH EROSION CONTROL PROJECT
BROADKILL BEACH, DELAWARE
2023 DAMAGE-FREQUENCY CURVE

FIGURE 5

SMALL BEACH EROSION CONTROL PROJECT

BROADKILL BEACH, DELAWARE

APPENDIX A

GEOMORPHOLOGY

U. S. ARMY ENGINEER DISTRICT

PHILADELPHIA, PA.

APPENDIX A

GEOMORPHOLOGY

1. The study area is located entirely within Sussex County, Delaware, and it extends along the Delaware Bay shore approximately 7 miles northwesterly from Cape Henlopen. The area lies within the Coastal Plain province of eastern United States, a physiographic province bordered on the west by the Piedmont province and extending eastward to the seaward edge of the continental shelf. It consists of both a subaerial and submerged portion, the present shoreline forming the boundary between them.

2. The most prominent physiographic features of the subaerial portion of the coastal plain are the Delaware and Chesapeake Bays, estuaries formed by the drowning of the Delaware and Susquehanna river valleys as sea level rose at the end of the last Pleistocene glacial stage. Topographic features and elevations within the coastal plain are expressions of the regional geology of the area. To the west, where the coastal plain abuts against the gentle slopes of the Piedmont province, there is a narrow strip of lowland occupied by the valley of Delaware River between Philadelphia and Wilmington, and by the upper reaches of Chesapeake Bay northeast of Baltimore. This lowland was formed by the wasting away of the easily eroded Raritan clay formation which underlies this area. The area to the southeast of this lowland is underlain by more resistant formations, Cretaceous and Tertiary in age, which form the higher land of the "Eastern Shore" of Maryland and Delaware. This area constitutes a plain with a maximum elevation of about 80 feet which has been maturely dissected by a branching drainage pattern of many small streams and creeks. As the coast is approached, the terrain flattens to a low, featureless plain underlain by formations of Miocene and Pleistocene age. Characteristic features of the shoreline are barrier beaches backed by low dunes separated from firm ground by extensive marshes and several bays.

3. Off the Delaware Coast the submerged portion of the Coastal Plain province or continental shelf extends seaward approximately 65 miles. Surveys made by the U. S. Coast and Geodetic Survey show it to be essentially a flat sandy plain with an average slope southeastward of 5 to 6 feet per mile. The bottom physiographic features are, in general, smooth rounded forms of low relief which have been described as northeast-southwest trending bars and depressions, and occasional prominent terraces

that are steep on the seaward side. These physiographic features are interpreted as former barrier beaches and lagoons formed during a period of progressively rising sea advancing across the shelf. The channel of Delaware River is traceable for approximately 50 miles across the continental shelf southeast of the entrance to Delaware Bay.

4. At the seaward margin of the continental shelf there is an abrupt change in the character and average slope of the bottom. Here in a distance of approximately 50 miles the continental slope drops from a depth of 600 feet to 8,000 feet and more below sea level. The surface of the slope is deeply and intricately dissected by numerous valleys and ridges with a local relief in many places much greater than that found in the Appalachian Mountains.

5. Four prominent submarine canyons indent the continental shelf of the coast between the entrances to Delaware Bay and Chesapeake Bay. Wilmington canyon, the northernmost of the four, is roughly latitudinal with the Delaware-Maryland State line. At one point it is 3,000 feet deep below its rim and about 5 miles wide. The head of this canyon cuts 10 miles into the shelf. Baltimore canyon, approximately 20 miles southwest of Wilmington canyon, is 2,400 feet deep below its rim and 3 miles wide at one place. This canyon also cuts about 10 miles into the shelf. There are strong indications that the Delaware River channel once connected with the Baltimore submarine canyon. The two remaining canyons are located south of Baltimore canyon.

6. The nearly continuous beaches bordering Delaware Bay are generally narrow with an average width of 10 to 50 feet at high water. At many locations the water reaches the foot of the low dunes behind the beach during periods of storm waves or unusually high tides. A belt of grass-covered dunes ranging 50 to several hundred feet in width and from 8 to 12 feet in height separates the beach from extensive salt marshes. At many places the dune crest is only 3 to 4 feet above the high water line. Salt marshes 0.5 to 2 miles in width separate the dunes from firm ground. Narrow bands of marsh follow the stream channels several additional miles inland. Numerous drainage ditches crisscross these marshes, as do the meandering channels of many small creeks. The marshes more or less coalesce except where a narrow strip of sandy soil joins the dunes to firm ground. These strips are utilized by the few roads leading to the beaches. Inland of the marsh the land is essentially flat with a very gradual rise in slope to the northwest.

7. DRAINAGE. The St. Jones, Murderkill, Mispillion and Broadkill Rivers, which empty into Delaware Bay, are the principal streams draining the bay shore area between Pickering Beach and Lewes. Except for the St. Jones, they are all less than 15 miles in length with low gradients. The lower courses of these streams meander through extensive marshes and are tidal for several miles inland. Although these streams flow through a region composed of sand and silt, the stream velocities are insufficient to transport any appreciable amount of sediment. What little material is carried, is deposited in the marshes, and practically none reaches the littoral zone to serve as a source of beach material.

8. The Lewes and Rehoboth Canal enters Delaware Bay at Roosevelt Inlet just west of Lewes and terminates about 1.5 miles south of Rehoboth in Rehoboth Bay. Several minor creeks and drainage ditches empty into this canal. Practically no sediment is furnished by this canal to nourish the beaches.

9. SURFICIAL GEOLOGY. The sedimentary formations comprising the surface of the coastal plain of Delaware outcrop in successive belts having a northeast-southwest trend. The oldest, of Cretaceous age, outcrops at the western edge of the coastal plain, and the succeeding overlapping formations are progressively younger as the shoreline is approached. Comparative mineral studies indicate that the original source of material comprising these sediments was derived through erosion of older rock formation in the Piedmont and Appalachian Mountain provinces to the west. Sedimentary formations of both marine and fluvial origin are represented. They were formed when sediments from the area to the west were deposited in the shallow waters overlying the coastal plain during periods of submergence, and along the stream valleys.

10. In general, these sedimentary formations are composed of unconsolidated and semi-consolidated material of Cretaceous, Eocene, Miocene, and Quaternary age. The cretaceous beds include sands, clays, and glauconitic marls; while the Eocene sediments are composed of glauconitic marls, lime sand, glauconitic quartz, sand, and clay. Fine micaceous sands and quartz sands with local beds of clay and gravel comprise the Miocene sediments. Quarternary formations, which are the most recent in age, are chiefly sands and gravels. The Quarternary can be further subdivided into the Pleistocene, or glacial period, and the Recent, or present day. Sedimentary deposits of Pleistocene age, particularly those occurring along the shores of the Delaware estuary, contain glacial debris transported there by melt waters, which flowed down the Delaware River valley, from the continental glaciers to the north. Recent sediments are represented by beach and dune sands and deposits of peat in the marshy areas.

11. Only three sedimentary geologic units are exposed at the surfaces of the coastal plain within the drainage limits of the study area. Since these formations are possible sources of beach material, they are described in detail.

12. The Wicominco formation of Pleistocene age is exposed at elevations above 25 feet. This includes the materials ranging in elevation from 25 to 42 feet, which are designated as the Talbot formation by some geologists. The sediments comprising the Wicomico formation range in size from clay and silt to sand and gravel. Although the upper courses of the streams draining the study area are cut in material of this formation, it is doubtful that their velocities are sufficient to transport a significant amount of material of a size greater than silt. Material that is carried is probably deposited in the marshy areas bordering the lower courses of the streams.

13. The Pamlico formation, also of Pleistocene age, forms the surface between sea level and the 25-foot elevation. This formation, of fluvial and estuarine origin, is primarily gravel, sand, and silt. Its maximum thickness probably does not exceed 30 feet. The lower courses of the streams are cut in material of this formation. Sluggish stream velocities and fringing tidal marsh prevent any appreciable amount of material of beach-building size from reaching the shoreline.

14. Overlying the Pamlico formation are deposits of recent age. These are chiefly tidal marsh, and beach and dune sands. The latter are presently being reworked by littoral forces and redistributed along the shore.

15. GEOLOGICAL HISTORY. The geological history of the Delaware area indicates that from Cretaceous time to the present, there has been continuous transgression and regression of ocean waters across the Coastal Plain province. At times the shoreline has been located west of Chesapeake Bay, and at other times it has been far to the east on the continental shelf. During periods of transgression, materials which eroded from the higher lands to the west were deposited in the shallow ocean waters overlying the coastal plain, in the estuaries which formed as river valleys became flooded, and in lagoons which formed behind barrier beaches. During periods of emergence the newly deposited sediments were exposed to erosion. Later they were submerged again, and overlapped and buried by younger sediments.

16. The dominant physiographic features of the coastal plain -- the long narrow lowland bordering the Piedmont province and the high ground of the "Eastern Shore" of Maryland and northwestern Delaware — were probably initiated during a period of erosion prior to Miocene time. During the Miocene period these features were nearly covered by a deposit of marine sediment, only to be uncovered and developed almost to their present form by post-Miocene erosion. In Pliocene time serveral broad areas of alluvium were deposited on the Coastal Plain by southeastwardly flowing streams, particularly the Delaware, Susquehanna, and Potomac Rivers. The distribution of these sediments suggests that material was first deposited along the pre-existing valleys, and as the valleys filled up, the alluvium spread over the intervalley areas forming a coalescent, nearly continuous alluvial plain sloping seaward. During a succeeding period of emergence this Pliocene surface between the Delaware and Potomac Rivers was maturely eroded, and the large valley that now constitutes the estuary of the Delaware River was formed. Some of the alluvial material deposited during Pliocene time was reworked and redeposited, and today constitutes the Wicomico formation.

17. The succeeding Pleistocene epoch is notable for the extensive continental glaciers, which alternately advanced southward from the north polar regions and then retreated. During the glacial periods when the ice sheet advanced, sea level was lowered considerably as large quantities of water which normally would have returned to the ocean remained on the land as snow and ice. During the interglacial stages, sea level rose as the glaciers melted, and the melt-water flowed to the ocean. This oscillation in the level of the sea caused the shoreline to migrate back and forth across the Coastal Plain.

18. FORMATION OF THE PRESENT SHORELINE. During the Wisconsin, or latest glacial stage, it is estimated that the level of the ocean reached a maximum low of between 230 and 300 feet below present sea level. This would place the shoreline about 60 miles east of the present Delaware coast. Recent time began with the end of the Wisconsin glacial stage, the gradual return of melt water to the ocean from the receding glaciers, and a consequent rise in sea level. This was caused by a progressive migration of the shoreline across the continental shelf and the formation of barrier beaches, bays and lagoons. Evidence of these are found in the physiography of the surface of the continental shelf, particularly in the elongated shoals with a

northeast-southwest trend, which suggests the location of former barrier beaches and bars. The glacial debris, which was spread over the continental shelf and the Delaware Valley, furnished abundance of material from which sand dunes were formed. Inland of the barrier beaches, lagoons formed, which eventually became marshes as they filled with sediment. As sea level continued to rise, the beaches were driven landward over the marshes.

19. This trend is still continuing. The shoreline follows the contour of the flooded land, the lower reaches of the stream valley are flooded, and many low areas have been converted into tidal marsh through the accumulation of silt and the growth of water plants. Barrier beaches have formed where the slope of the coastal plain is too gentle to afford a profile of equilibrium for shore processes. Exposed tree stumps, in the position of growth, in front of the large dune on Cape Henlopen and exposed marshes along the foreshore of many Delaware Bay beaches indicate that the migration of the beaches is still continuing.

20. Recent studies indicate that sea level is continuing to rise at a very slow rate with respect to the land. Whether this represents an actual rise in water level or a subsidence of the land has not yet been determined. This relative rise of the sea level plus the lack of an adequate source of material for beach nourishment will effect a continued landward migration of the beaches.

SMALL BEACH EROSION CONTROL PROJECT

BROADKILL BEACH, DELAWARE

APPENDIX B

LITTORAL MATERIALS

U. S. ARMY ENGINEER DISTRICT

PHILADELPHIA, PA.

APPENDIX B

LITTORAL MATERIALS

1. GENERAL. The available information concerning physical characteristics of the littoral materials along the shores of Delaware dates back to 1929. Prior to 1954 only a limited number of samples were taken, and those were confined to the beach areas above mean low water. The locations of samples along the beach profiles and the methods of analysis were not always consistent for different groups of samples, hence available data cannot be readily correlated or compared with the later data obtained from surveys conducted in 1954, 1964 and 1969 by the Corps of Engineers.

2. Samples of beach and offshore surface material were taken during the 1954, 1964 and 1969 surveys. Samples taken during the 1954 and 1969 surveys were subjected to a mechanical analysis using standard sieves, and the cumulative grain size gradation curves were determined for each. Samples taken during the 1964 survey were analyzed by using a visual accumulation tube apparatus. (The visual accumulation tube provides satisfactory results only if the samples have grain size diameters ranging from 0.06 to 1.00 millimeter. Therefore, the sieve analysis method was used for those samples too coarse for the visual (accumulation tube) analysis).

3. Thirty samples were taken in the Broadkill Beach vicinity during the 1954 survey by the Corps of Engineers. Those samples were obtained along profiles normal to the shoreline at approximately one mile intervals and are representative of the littoral material above mean high water, in the mid-tide zone, and from the nearshore bottom. Five samples were obtained on each of the six profiles surveyed in the vicinity of Broadkill Beach. The beach samples were taken from the surface to a depth of two inches, and the underwater samples represented the top 1 to 2 inches of material.

4. A total of 12 samples were taken during the 1964 survey by the Corps of Engineers. Samples were obtained along only two of the eight lines surveyed in 1964 along the Delaware Bay shore. The distance between sampled profiles is 1.5 miles. The beach samples obtained in 1964 were taken from a depth of between 2 and 4 inches below the surface. The underwater samples were taken from the top several inches.

5. A total of 25 samples were taken in the vicinity of Broadkill Beach during the 1969 survey by the Corps of Engineers. The distance between sampling profiles varied from 300 to 400 feet. Five samples were taken along five lines. The beach samples were taken from the surface to a depth of 4 inches.

6. CHARACTERISTICS GENERAL.

a. General. The three statistical constants often used to describe littoral materials are the median diameter (M), coefficient of sorting (S_o) and the skewness (S_k). These constants are adequate for use in general descriptions of the littoral materials along a shoreline and are derived from the diameters at the 25th, 50th and 75th percentiles of the cumulative grain size distribution graphs. However, they are not considered adequate in specifying sand for beachfill. The method used for specifying sand for areas of proposed beachfill is that given in Beach Erosion Board (now the Coastal Engineering Research Center) Technical Memorandum No. 102. As indicated in Technical Memorandum No. 102, the geometric mean diameter (G.M.) and the geometric standard deviation (G.S.D) are more descriptive constants for use in specifying beachfill. The G.M. and the G.S.D. for a given sample are determined as follows:

G.M. (mm) = $\sqrt{d16 \times d84}$, and G.S.D. = $\sqrt{d16 \div d84}$, where d_{16} and d_{84} are respectively, the grain size diameters at the 16th and 84th percentiles of the cumulative grain size distribution of the sample. Thus, it is apparent that a greater portion of the sample's grain size distribution is being accounted for in determining these coefficients (16% to 84% vs. 25% to 75%). Neither the G.M. nor the G.S.D. was determined for the samples taken prior to 1964. Consequently, the discussions below use the M, S_o, and S_k coefficients in describing the littoral materials, making comparisons of data, and analyzing changes that have occurred. However, the geometric mean diameter and the geometric standard deviation were determined for the 1964 and 1969 samples, and these data are presented on table B-1 for samples taken in the study area. The underwater samples from Delaware Bay have scattered deposits of silts. However, the beach samples indicate sands in the fine-to-medium size range classification. The mid-tide samples have geometric mean diameters varying between 1.26 and 2.60, indicating sands in the medium-to-coarse size range.

SIZE CHARACTERI

Profile No.	Sampling Date	BEACH SAMPLES										S
		Above M.H.W.					Mid-Tide					
		No.	Sta.	Elev	G.M.	G.S.D.	No.	Sta.	Elev	G.M.	G.S.D.	[illegible]
25	3 July 64	1	-(3+00)	+9.2	0.44	1.64	4	1+30	+2.0	--	--	3
		2	0+40	+8.2	--	--						
		3	0+85	+4.2	1.50	3.94						
25	Sept [illegible]	1	--	+4.2	0.32	1.24	2	--	+2.0	0.71	1.54	
25AA 1/	Sept [illegible]	1	--	+4.2	0.[illegible]	2.48	2	--	+2.0	2.36	3.58	
25A	Sept [illegible]	1	--	+4.2	0.31	1.29	2	--	+2.0	1.67	2.84	
25BB 2/	Sept [illegible]	1	--	+4.2	0.28	1.45	2	--	+2.0	0.43	1.72	
25B	Sept [illegible]	1	--	+4.2	0.25	1.30	2	--	+2.0	0.43	1.50	
25	[illegible] July 64	1	-(3+00)	+5.[illegible]	0.36	[illegible]	3	[illegible]	+2.0	2.82	2.[illegible]	6
		2	0+50	+[illegible]	0.8[illegible]	2.04						

1/ Profile line located between lines 25 and 25A which are shown on plate 3.

2/ Profile line located between lines 25A and 25B which are shown on plate 3.

TABLE B-1

CTERISTICS OF LITTORAL MATERIAL - BROADKILL BEACH, DELAWARE

									UNDERWATER SAMPLES						
	Sampling	Sta. 12+00 to 20+00					Sta. 24+00 to 32+00					Sta 35+00 to 43+00			
D.	Date	No.	Sta	Elev	G.M.	G.S.D.	No.	Sta.	Elev	G.M.	G.S.D.	No.	Sta.	Elev	G.M.
	3 July 64						5	30+75	-5.2	0.34	1.35				
	6 July 64	4	14+60	-6.0	VF							5	41+40	-12.0	VF

UNDERWATER SAMPLES

+00			Sta 35+00 to 43+00					Sta. 47+00 to 66+00			
G.M.	G.S.D.	No.	Sta.	Elev	G.M.	G.S.D.	No.	Sta	Elev	G.M.	G.S.D.
0.34	1.35						6	52+85	-10.2	0.34	1.38
		5	41+40	-12.0	VF		6	56+45	-13.6	VF	

b. Median diameter. The median diameter (generally expressed in millimeters) represents the midpoint of a sample's cumulative grain size distribution. Fifty percent of the total weight of a sample is composed of particles having diameters greater than the median diameter and fifty percent has particles with grain sizes smaller.

c. Coefficient of sorting. This coefficient indicates the degree of sorting or the measure of spread in grain sizes of the material. It is obtained from the following formula:

$$S_o = \sqrt{Q_1 / Q_3}$$

where S_o is the coefficient of sorting, and Q_1 and Q_3 are the grain size diameters at the first and third quartiles, respectively, of the sample's cumulative grain size distribution curve. Twenty-five percent by weight has grain diameters larger than the diameter of the first quartile and seventy-five percent has grain diameters larger than the third quartile. If there were perfect sorting, the value of the coefficient of sorting would be unity. According to Stetson 1/, a value of 1.25 is indicative of good sorting for samples of the beach material, and 1.45 indicates good sorting for materials in the nearshore bottom.

d. Skewness. This coefficient indicates on which side of the median diameter, and how far from it, the point of maximum sorting lies. It is derived from the formula:

$$S_k = \frac{Q_1 Q_3}{M^2}$$

where S_k is the skewness, and M is the median diameter. The amount of skewness is conveniently expressed by the two-place logarithm of S_k. Positive values of log S_k (representing a coefficient of skewness greater than unity) indicates that the maximum sorting is found in particle sizes finer than the median diameter; negative values of log S_k (S_k less than unity) indicates maximum sorting in sizes coarser than M.

1/ Stetson, Henry C., The Sediments of the Continental Shelf of The Eastern Coast of the United States, Papers in Physical Oceanography and Meterorology, Mass. Inst. of Technology and Woods Hole Oceanographic Institution, Vol. 5, No. 4, July 1938.

e. Interpretation of statistical constants. The higher the value for the median diameter the coarser is the material; the larger the value for the coefficient of sorting the more poorly sorted is the material; and more the value for skewness diverges from unity the more unsymmetrical is the size distribution curve. According to Stetson:

> Small values for both S_o and S_k indicate a well sorted sediment in which the peak of the size distribution lies near the median diameter, one which is in adjustment with its environment, and is therefore transported, deposited, and maintained by a narrow range of conditioning factors ... It is possible to have a large value for S_o accompanying a small S_k. This indicates that though the peak of the size distribution nearly coincides with the median, it is not well developed, and the material is spread evenly through many grade sizes.
>
> "A small value for S_o and a large S_k likewise indicate that a given sample ranges through many grades sizes, but with the important difference that the frequency curve would show a well developed peak, and relative to it the proportion of more poorly sorted material would be smaller." It indicates that one set of environmental factors is dominant, though traces of others are still retained.
>
> "Large values for S_o and S_k indicates that the sediment is completely out of adjustment with the environment in which it is found."

7. CHARACTERISTICS OF LITTORAL MATERIALS - DELAWARE BAY SHORE.

a. General. Beach samples were taken by the Beach Erosion Board (now the Coastal Engineering Research Center), in October 1954 at several locations along the Delaware Bay shore. The samples were taken at the mid-tide level to a depth of two inches. The samples were subjected to a mechanical analysis using standard sieves and the results from the samples at Broadkill Beach are presented in table B-2, which shows the median diameter, the coefficient of sorting, and the log of the coefficient of skewness.

TABLE B-2

SAMPLES FROM SURVEYS OF OCTOBER 1954
BROADKILL BEACH, DELAWARE
(Beach samples at mid-tide level)

Median Diameter (mm)	Coefficient of Sorting	Log Skewness
0.59	1.57	-0.09

b. Table B-3 lists the general location, profile line number, and the date during which the samples were taken for each the 1954, 1964 and 1969 surveys. Samples taken from above mean low water are designated as "Beach Samples" and those samples from below mean low water as "Underwater Samples". The relative position of the various samples along a given profile can be determined by the sample number, since each sample location is numbered consecutively from the landward to the bayward end of the profile. Because of the flat offshore bottom slopes, data for the underwater samples are presented according to their profile station location. Samples obtained in 1954, 1964 and 1969 generally fall within the station zones indicated in the column headings on the table. Station 0+00 is at the 1964 survey line reference point of each profile, and generally is located near the top of the dune. The size characteristics tabulated are the median diameter (M), the coefficient of sorting (S_o), and the log of the coefficient of skewness (log S_k).

8. CHARACTERISTICS OF BORROW AREA. Investigation of probable sources of borrow consisted of field reconnaissances and review of subsurface data from borings performed from 1952 to 1962. The information available indicates that the most promising source of borrow for beach replenishment is an area in Delaware Bay located less than one mile offshore of Broadkill Beach. Test results of samples taken for the State of Delaware in a portion of this area show that materials available from 5 to 25 feet below the bay bottom are of a size range which should provide a more stable beachfill with moderate losses due to the sorting action to which it will be subjected. Although the borings on which the choice of this borrow area is based were located in an area which was explored in 1962, it is expected, based on the area geology, that material of comparable quality is available in areas adjacent to that investigation by the State of Delaware. It is anticipated that adequate quantities of material for this initial replenishment and periodic nourishment of the beaches will be available from this offshore source. Figure B-1 shows the composite grain size curve for the borrow area and the existing beach and illustrates the coarser characteristics of the borrow area which should result in a more stable beach.

SIZE CH

Profile No.	Sampling Date	BEACH SAMPLES: Above M.H.W. No.	Elev	M	S_o	Log S_k	Mid-Tide No.	Elev	M	S_o	Log S_k
25	3 July 64	1	+9.2	.40	1.41	.03	4	+2.0	--	--	--
		2	+8.2	--	--	--					
		3	+4.7	.77	2.68	.34					
(20A)	Aug-Oct 54	1	--	--	--	--	2	--	--	--	--
25	Sept 69	1	+4.2	.32	1.54	.05	2	+2.0	.40	1.40	.04
25AA	Sept 69	1	+4.2	.51	1.49	.14	2	+2.0	1.8	2.38	.08
25A	Sept 69	1	+4.2	.31	1.14	-.07	2	+2.0	2.6	1.39	.06
25BB	Sept 69	1	+4.2	.25	1.22	-.02	2	+2.0	.45	1.33	-.08
25B	Sept 69	1	+4.2	.23	1.20	.04	2	+2.0	.40	1.34	.09
28	6 July 64	1	+5.6	.33	1.35	.04	3	+2.0	2.00	2.19	.10
		2	+6.0	.71	1.48	-.18					
(23)	Aug-Oct 54	1	--	--	--	--	2	--	1.30	1.49	.05

TABLE B-3

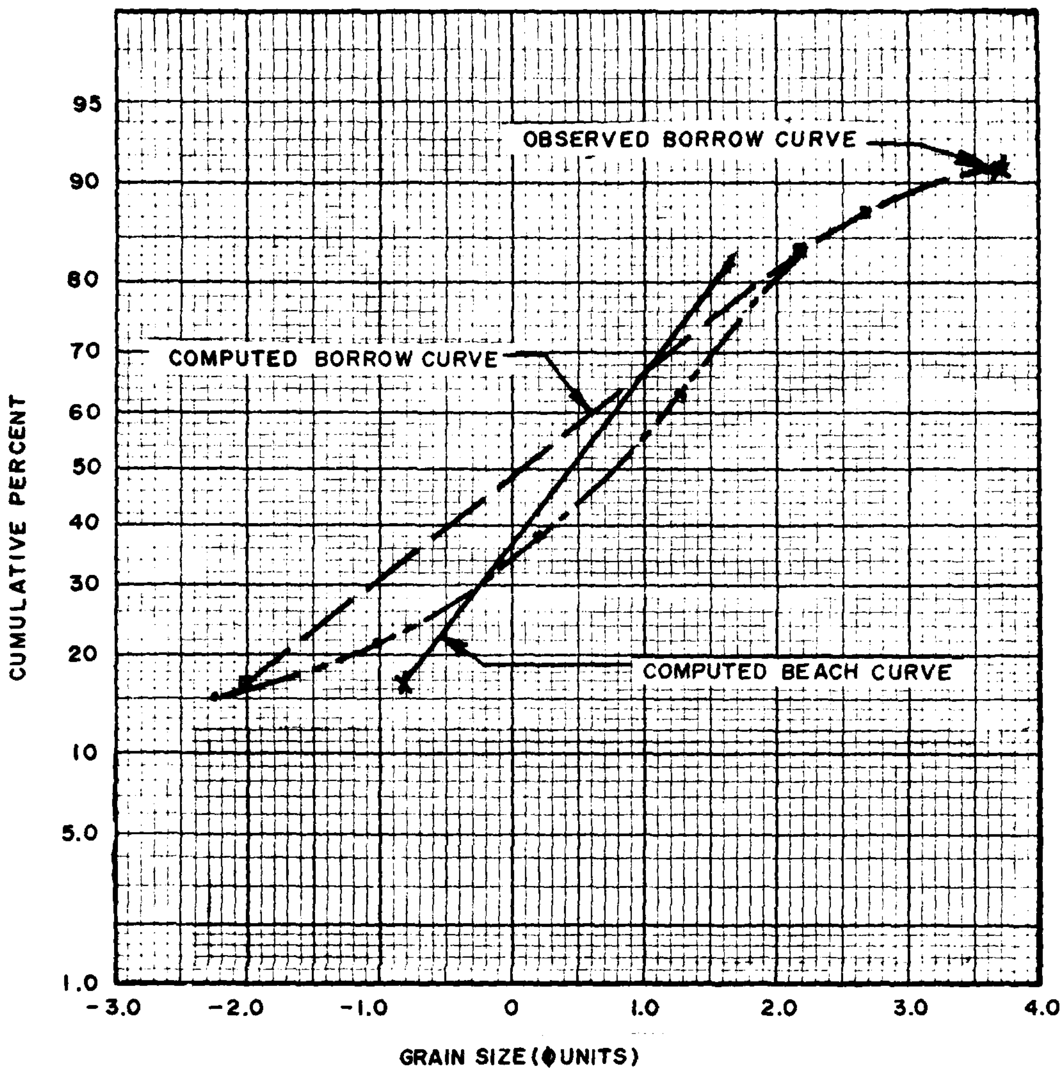
SIZE CHARACTERISTICS OF LITTORAL MATERIAL - BROADKILL BEACH DELAWARE

		UNDERWATER SAMPLES														
	Sampling	Sta. 12+00 to 20+00					Sta. 24+00 to 32+00					Sta. 35+00 to 43+00				
og S_k	Date	No.	Elev	M	S_o	Log S_k	No.	Elev	M	S_o	Log S_k	No.	Elev	M	S_o	Lo
--	3 July 64						5	-5.2	.34	1.31	.03					
--	Aug-Oct 54	3	--	.48	1.68	.10	4	--	.20	1.41	.20					
.04																
.08																
.06																
-.08																
.09																
.10	6 July 64	4	-6.0	VF								5	-12.0	VF		
.05	Aug-Oct 54	3	--	.11	--	--	4	--	.11	--	--					

WARE

UNDERWATER SAMPLES

24+00 to 32+00				Sta. 35+00 to 43+00					Sta. 47+00 62+00				
ev	M	S_o	Log S_k	No.	Elev	M	S_o	Log S_k	No.	Elev	M	S_o	Log S_k
.2	.34	1.31	.03						6	-10.2	.32	1.24	.02
.	.20	1.41	.20										
				5	-12.0	VF			6	-13.6	VF		
	.11	--	--										



MATERIAL	ϕ_{84}	ϕ_{16}	$M\phi$	$S\phi$
BEACH (ALL KINDS)	1.74	-0.80	0.47	1.27
BORROW (B7,8,9,11)	2.18	-2.00	0.09	2.09

x———x BEACH-LINES 25,25AA,25BB,25B-COMPUTED CURVE TM 102 METHOD.

■— —■ BORROW-STATE OF DEL. BORINGS (1962) B7,B8, B9,B11 (COMPUTED CURVE).

•— - —• BORROW-STATE OF DEL. BORINGS-OBSERVED CURVE BY WEIGHTED AVG. METHOD.

SMALL BEACH EROSION CONTROL PROJECT
BROADKILL BEACH, DELAWARE
COMPUTED COMPOSITE
GRAIN SIZE DISTRIBUTION

FIGURE B-1

BY	DATE 2/[illegible]	SUBJECT [illegible] Beach Fill	SHEET NO. OF
CHKD. BY	DATE	Beach Erosion Control Project	JOB NO.
		Determination of Borrow Ratio	

CERC TM 16 METHOD – Method requires extra fill to be placed when the borrow is either coarser or finer than the beach sand

BEACH SAND $\phi_{16} = -0.80$, $\phi_{84} = 1.74$ (Computed composite size curve for sample lines 25, 25 AA, 25 A, & 25 BB)

BORROW Gradation (weighted average) from borings 7, 8, 9 & 11 is:

SIEVE SIZE	#4	#10	#20	#40	#100	#200
% PASSING	15	21	38	62	88	91

$\phi_{16} = -2.00$, $\phi_{84} = 2.18$

This gradation data shows that the borrow material is coarser than the beach sand.

CRITICAL RATIO TM-16

$$R\phi = \frac{S\phi_b}{S\phi_n}\left[e^{-\frac{(M\phi_n - M\phi_b)^2}{2(S\phi_n^2 - S\phi_b^2)}}\right]$$

$M\phi_b = \frac{\phi_{84} + \phi_{16}}{2} = \frac{2.18 + (-2.00)}{2} = 0.09$ = Phi mean of borrow mat'l

$M\phi_n = \frac{1.74 + (-.80)}{2} = 0.47$ = Phi mean of native beach material

$S\phi_b = \frac{\phi_{84} - \phi_{16}}{2} = \frac{(2.18) - (-2.00)}{2} = 2.09$ = Standard deviation of borrow mat'l in ϕ units

$S\phi_n = \frac{1.74 - (-.80)}{2} = 1.27$ = Standard deviation of beach materials in ϕ units

$$R\phi = \frac{2.09}{1.27}\, e^{-\frac{(0.09 - 0.47)^2}{2((1.27)^2 - (2.09)^2)}} = 1.65\, e^{0.0262} = 1.69$$

Note:

The difference between this ratio and the 1.66 used for [illegible] engineering [illegible] and therefore the 1.66 used in the draft report was not changed for this final report.

FIGURE B-2

SMALL BEACH EROSION CONTROL PROJECT

BROADKILL BEACH, DELAWARE

APPENDIX C

ESTIMATES OF COST

U. S. ARMY ENGINEER DISTRICT

PHILADELPHIA, PA.

APPENDIX C

ESTIMATES OF COST

ESTIMATE OF FIRST COST

1. GENERAL. The first cost of providing the proposed improvement is estimated to be $243,000 1/. This cost is based on price levels of July 1971 and includes allowances for contingencies, engineering and design, and supervision and administration. The estimates for the various items of work were made as described in the following paragraph and they are summarized in table C-1.

TABLE C-1

ESTIMATE OF FIRST COST

Beachfill	110,000 c.y.	@ $1.71/c.y.	$187,916
Sand Fence	4,500 ft.	@ $1.20/ft.	5,400
		Subtotal	$193,316
Contingencies @ 15%			28,997
Engineering and design			14,479
Supervision and administration			5,973
		Total first cost 1/	$242,765
		SAY	$243,000

2. BEACH FILL. The estimated cost of placing 110,000 cubic yards of beachfill on the beach of the study area was based on a 14-inch pipeline dredge pumping from a borrow source about 1000 feet offshore. The estimate includes an overrun allowance factor of 66 percent. A detailed estimate for placing this beachfill is given in table C-2.

1/ Exclusive of preauthorization study costs of $25,300.

TABLE C-2

TOTAL AND UNIT COST OF PLACING BEACHFILL

1.	Estimated quantity to be placed	
	a. Initial fill	110,000 c.y.
	b. Overpumpage @ 66 percent	72,600 c.y.
	c. Total volume to be placed	182,600 c.y.
2.	Output of 14-inch pipeline dredge per month (340 c.y./hr. x 17 hrs/day x 25 days/month)	144,500 c.y.
3.	Time required to complete job	1.26 mo.
4.	Monthly cost of dredge and plant	$95,440
5.	Total cost of work to contractor	
	a. Total plant operating cost 1.26 x $95,440	$120,254
	b. Ranges, field engineering, inspection, etc.	2,874
	c. Mobilization and demobilization	14,629
	d. Payroll, state and local taxes	13,637
	e. Subtotal	$151,394
	f. Contractors overhead 12%	18,167
	g. Bond cost (3/4% of 5e and 5f)	1,272
	h. Subtotal	$170,833
	i. Contractors profit 10%	17,083
	j. Subtotal	$187,916
	k. Estimated cost per cubic yard 5j ÷ 1a	$1.71/c.y.

3. PERIODIC NOURISHMENT. The estimated cost of nourishing the beach every four years was based on a 10-inch pipeline dredge pumping from a borrow site about 1,000 feet offshore. The estimate includes an overrun factor of 66 percent. A detailed estimate for placing this beachfill, every four years, is given in table C-3. An estimate of the cost of placing beachfill along with allowances for contingencies, engineering and design, and supervision and administration every four years and an estimate of the annual cost is given in table C-4.

TABLE C-3

TOTAL AND UNIT COST OF PLACING NOURISHMENT

1.	Estimated quantity to be placed	
	a. Necessary nourishment	40,000 c.y.
	b. Overpumpage @ 66 percent	26,400 c.y.
	c. Total volume to be pumped	66,400 c.y.
2.	Output of 10-inch pipeline dredge per month (25 day month)	$85,000 c.y.
3.	Time required to compete job	0.78 mo.
4.	Monthly cost of dredge and plant	$58,900
5.	Total cost of work to contractor	
	a. Total plant operating cost (0.78 x $58,900)	$45,942
	b. Ranges, field engineering, inspections, etc.	1,103
	c. Mobilization and demobilization	12,546
	d. Payroll, state and local taxes	5,205
	e. Subtotal	$64,796
	f. Contractors overhead 12%	7,776
	g. Bond cost (3/4% of 5e and 5f)	544
	h. Subtotal	$73,116
	i. Contractors profit 10%	7,312
	j. Subtotal	$80,428
	k. Estimated cost per cubic yard 5j ÷ 1a	$2.01/c.y.

TABLE C-4

ESTIMATE OF COST OF NOURISHMENT EVERY 4 YEARS

Beachfill 40,000 c.y. @ $2.01/c.y.	$80,428
Contingencies @ 15%	12,064
Engineering and design	6,016
Supervision and administration	2,493
	$101,001

$101,001 every 4 years

Annual cost = $101,001 x (SFF for i = 5-3/8% and n = 4 yrs.)

= $101,001 x 0.230722

= $23,303

SAY $23,300

ANNUAL CHARGES

4. GENERAL. Annual charges consist of interest and amortization on the first cost of the proposed plan of improvement, and the annual maintenance and periodic nourishment costs. Interest and amortization charges were computed at the rate of 5-3/8 percent for an economic life of 50 years. Since the proposed improvement can be constructed in less than one year, no charge for interest during construction has been included. The estimated annual charge of the proposed improvement is $39,200 as shown in table C-5.

TABLE C-5

SUMMARY OF ESTIMATED ANNUAL CHARGES

First Cost	$243,000
Interest and amortization @ 5-3/8% for 50 years 0.057981	14,089
Periodic nourishment	23,300
Maintenance of sand fence $5400 ÷ 3	1,800
	$39,189
SAY	$39,200

APPORTIONMENT OF COSTS

5. GENERAL. The policy governing Federal participation in the construction of structures and related works for the improvement and protection of shores where public benefits are involved, is set forth in Public Law 84-826, as amended by Public Law 87-874. The Federal share of the cost of the project will normally be equal to 50 percent of the first cost of construction of works for the protection of shores owned by non-Federal public agencies, plus a share of the costs of protecting privately-owned shores where public benefits will result. For privately-owned shores, the 50 percent maximum allowable Federal contribution is adjusted by the rate of public benefits to total benefits accruing to those shores as a result of the project. The entire study area is privately-owned, however, there is no restriction to use of the beach and it is accessible to the public. Therefore, protection will result in public benefits. Public benefits derived from the proposed project would represent 46.2 percent of the total benefits. The Federal contribution toward the construction of the proposed improvements is determined from the following:

$$\left[\frac{\text{Public shore}}{\text{Total shore}} + \left(\frac{\text{Private shore}}{\text{Total shore}} \times \frac{\text{Public benefits along private shore}}{\text{Total benefits along private shore}}\right)\right] \times 0.5 \times 100,$$

where 0.5 represents, the maximum allowable Federal share discussed above. Therefore, the Federal percentage of the first cost of providing the proposed plan of protection would be:

$$\left[\frac{0}{4{,}500} + \left(\frac{4{,}500}{4{,}500} \times \frac{24{,}100}{52{,}200}\right)\right] \quad 0.5 \times 100 = 23.1$$

The total Federal share of the first cost of construction would be 23.1 percent of $243,000 or $56,100. The Federal share of the annual cost of periodic beach nourishment would be 23.1 percent of $23,300 or $5,380.

SMALL BEACH EROSION CONTROL PROJECT

BROADKILL BEACH, DELAWARE

APPENDIX D

STATEMENTS OF OTHER AGENCIES

U. S. ARMY ENGINEER DISTRICT

PHILADELPHIA, PA.

STATE OF DELAWARE
EXECUTIVE DEPARTMENT
DOVER

RUSSELL W. PETERSON
GOVERNOR

January 6, 1972

Colonel Carroll D. Strider
Corps of Engineers
Department of the Army
Custom House
2nd and Chestnut Streets
Philadelphia, Pennsylvania 19106

Dear Colonel Strider:

In response to your notice of the Public Meeting on the small beach erosion control projects for Lewes and Broadkill Beach, Delaware, I would like to submit the following statement:

I have requested the appropriate departments to review the information made available in the announcement of the Public Meeting. We generally support the Corps' recommendations, and hereby commit the State to its cooperation and assistance in seeing these projects through to completion.

I want to thank you on behalf of the people of Delaware for the U. S. Army Corps of Engineers' response to the request made to Mr. Davidson, Director of the State Highway Department in 1966, to undertake a study of beach erosion problems to protect the shoreline, in these areas, from further erosion. This hearing tonight represents, in part, the culmination of the Corps' study and its recommendations.

As you are aware, we are very concerned about the need to protect the natural environment along Delaware's coastline. We are making every effort to preserve this vital natural resource. It is one of my principal goals for the future well being of the State of Delaware.

I welcome this opportunity, the evening of January 6, to make my views known.

Sincerely,

Russell W. Peterson

Russell W. Peterson
Governor

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
U. S. POST OFFICE AND COURTHOUSE
BOSTON, MASSACHUSETTS 02109

January 25, 1972

District Engineer, Philadelphia District
U. S. Army Corps of Engineers
Custom House - 2nd and Chestnut Streets
Philadelphia, Pennsylvania 19106

Dear Sir:

This letter constitutes our report on the proposed improvement for beach erosion control at Broadkill Beach, Sussex County, Delaware.

The study was authorized by section 103 of the River and Harbor Act of October 23, 1962. This report was prepared under the authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661-666 inc.) in cooperation with the Delaware Department of Natural Resources and Environmental Control. It also represents the views of the National Marine Fisheries Service and reflects revisions made to your original project plans. It has the concurrence of these agencies, as indicated by letter dated September 30, 1971 and memorandum dated September 21, 1971, respectively.

We understand the project plan consists of improving 4,500 feet of beach, extending from a point 2,700 feet north of the access road at Broadkill Beach to a point 1,800 feet south by: (1) placing approximately 110,000 cubic yards of sand on the beach to provide a berm 50 feet wide at an elevation 10 feet above mean low water (mlw), (2) erecting 4,500 feet of sand fence, and (3) placing approximately 42,000 cubic yards of suitable sand on the beach for periodic nourishment every four years over the 50-year life of the project. Construction of two timber groins, included in previous plans, have been deleted.

We also understand that material for initial fill and periodic nourishment will come from an offshore borrow source instead of from a selected upland borrow area as originally planned. The borrow area will

be dredged to a depth of approximately 30 feet.

Due to the summer colony-type development and use characteristic of the project area, wildlife resources are of negligible value. The coastal marshes located behind and protected by the barrier beach are considered to be a major segment of the Atlantic Flyway and are heavily utilized by waterfowl as resting and feeding areas during migration periods. These marshes also support a local population of ducks which provide hunting opportunity during the waterfowl hunting season.

The Bay area contains moderate to good fish and shellfish resources. Migrating marine fishes such as weakfish, striped bass, summer and winter flounder, and black drum support the area's sport fishery. American shad, porgy, white perch, and Atlantic croaker are also harvested. The offshore borrow area supports a gill net fishery which contributes to the local economy. Shellfish resources include hard clams, oysters, and blue crabs.

Dredging of sand fill to a depth of 30 feet below mlw will result in losses of shellfish resources. Such adverse effects could be minimized by reduction of the dredged depth to 10 feet or less below mlw and a dredging procedure characterized by a shallow, level sweep.

Moreover, dredging of the borrow area to 30 feet, as planned, could create a stagnant pool with excessive concentrations of toxic gases due to decomposition of accumulated materials. This could be prevented through seaward extension of the borrow area to a point where the natural bottom is at an equal or greater depth than the borrow area.

In consideration of preserving our aquatic resources, we recommend:

1. that the dredged area not exceed a depth of 10 feet below

mlw and be continuous with the seaward area of equal or greater depth.

2. That dredging be conducted by a level, sweep-type procedure.

Sincerely yours,

Richard E. Griffith

Regional Director

Asso. Reg. Supvr._____
Corps Projects_____
2 Special Studies (C)___
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STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
Dover, Delaware 19901

September 30, 1971

Austin N. Heller,
Secretary

Mr. Donald Reese
Assistant Regional Director
U. S. Department of the Interior
Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
U. S. Post Office and Courthouse
Boston, Massachusetts 02109

Dear Mr. Reese:

Your letter of September 16, 1971 calling for our review and comments of your draft report concerning the proposed improvement for beach control erosion at Broadkill Beach, Sussex County, Delaware, has been received.

This matter has been reviewed and the project recommended by this Department, the Delaware Water and Air Resources Commission and by Governor Russell W. Peterson.

This Department concurs with your recommendations that the dredged area not exceed a depth of ten feet below mlw, be continuous with the seaward area of equal or greater depth, and that dredging be conducted by a level, sweep-type procedure.

This concurrence is based on the assumption that suitable materials and dredging conditions can be found at the depth indicated and that the borrow pit will not constitute a hazzard to bathers.

Sincerely,

Austin N. Heller
Secretary

RECEIVED
OCT 5 1971
R. N. S.

c/c
Please send copy to UWAO ... sent

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Water Resources Division
Federal Building - 14 Elm Street
Gloucester, Massachusetts 01930

Date: September 21, 1971

Reply to Attn of: FNE

Subject: Report draft review - Beach erosion control at Broadkill Beach, Sussex County, Delaware

To: Regional Director, BSFW, Boston, Mass.

We concur with your subject draft report and especially with the recommendation that the dredged area not exceed a depth of 10 feet below mean low water and be continuous with the seaward area of equal or greater depth.

William T. Gordon

for Russell T. Norris
Regional Director

RECEIVED
SEP 23 1971
R. B. S.

PUBLIC HEALTH SERVICE

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE
Region II
42 Broadway
New York, New York 10004

October 23, 1967

In reply refer to:
24:SE

Mr. H. F. Michel
Chief, Engineering Division
Department of the Army
Philadelphia District, Corps of Engineers
Custom House - 2 D & Chestnut Streets
Philadelphia, Pennsylvania 19106

Dear Mr. Michel:

This is in regard to your request for comments concerning the proposed beach erosion control project at Broadkill Beach, Delaware. The project is to consist of: (1) the placing of approximately 51,000 cubic yards of sand along the beach; (2) the erection of 4,500 feet of sand fence; (3) construction of two timber groins north of the existing groin field; and (4) the placing of approximately 42,000 cubic feet of sand as periodic nourishment every four years over the 50-year life of the project.

We have consulted with the Delaware State Board of Health on this project and have conducted an on site inspection of the project area. We have no objections to the project. We would suggest that should the fill material be obtained from a dredging operation, the Delaware State Board of Health and the Delaware Commission of Shellfisheries be notified. This would allow these agencies to close any shellfish areas affected and permit relaying of any shellfish resource that otherwise might be destroyed..

Sincerely yours,

R. J. Van Derwerker

Ralph J. Van Derwerker
Regional Program Chief
Water Supply & Sea Resources Program

UNITED STATES
DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
Northeast Region
2303 J.F. Kennedy Fed. Office Bldg.
Boston, Mass. 02203

October 16, 1967

Mr. H. F. Michel
Chief, Engineering Division
U.S. Department of the Army
Corps of Engineers
U.S. Custom House, 2nd & Chestnut Sts.
Philadelphia, Pennsylvania 19106

Dear Mr. Michel:

This office has no objection to the Corps of Engineers' beach erosion control project at Broadkill Beach, Delaware, so long as the sand used for the berm and for periodic nourishment does not contain organic materials that would putrify on the beach or wash into adjacent bay waters. Adequate provisions should also be made to insure control of any pollution associated with the proposed project which might be in violation of water quality standards set by the State of Delaware.

Sincerely yours,

L M Klashman

Regional Director

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF OUTDOOR RECREATION
128 N. BROAD STREET
PHILADELPHIA, PENNSYLVANIA 19102

IN REPLY REFER TO:
D64

Your ref:
NAPEN-R

October 20, 1967

District Engineer
Corps of Engineers
Custom House - 2nd and Chestnut Streets
Philadelphia, Pennsylvania 19106

Dear Sir:

We submit the following comments concerning the proposed small beach erosion control project at Broadkill Beach, Delaware, as requested by Mr. H. F. Michel, of your staff, in a letter dated September 29.

Generally, we favor beach erosion control projects, since from a recreation standpoint, they may preserve or create areas of coastal shoreline desirable for outdoor recreation opportunity provided public access is assured.

It is our understanding thet the project consists of preserving the shoreline of Broadkill Beach which apparently is a small summer resort area. With the liklihood of restricted public access, we assume that only minimum benefits were attributed to general recreation.

Based upon the limited information supplied, we consider the project desirable.

Sincerely yours,

Rolland B. Handley
Regional Director

By Earl C. Nichols
Earl C. Nichols

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF OUTDOOR RECREATION
FEDERAL BUILDING
1421 CHERRY STREET
PHILADELPHIA, PENNSYLVANIA 19102

IN REPLY REFER TO:

December 30, 1971

Colonel Carroll D. Strider
District Engineer
Philadelphia District
Corps of Engineers
Custom House, 2nd & Chestnut Sts.
Philadelphia, Pa. 19106

Dear Colonel Strider:

We received your December 17, 1971 letter announcing the public meeting at 7:30 p.m. at the Cape Henlopen High School to discuss the proposed plans of improvement that have been developed for the beaches of Broadkill Beach and Lewes, Delaware.

Our most recent comments on the proposed project at Broadkill Beach were made on April 27, 1971 and concerned our review of the draft environmental statement. Our previous comments on the project were made on October 20, 1967.

Our most recent comments on the Lewes, Delaware project were made on July 12, 1967. In our 1967 comments on the projects, we stated that in general we favor beach erosion projects since they may preserve or create areas of coastal shoreline for outdoor recreation opportunities.

Since the descriptions in the announcement of the meeting show the proposed measures for Lewes as substantially the same and those proposed for Broadkill Beach only slightly less in total impact, our earlier comments on these projects would still be applicable.

We hope, although at the present time we cannot be sure, that a representative from our agency will be able to attend the meeting.

Sincerely yours,

Rolland B. Handley

Rolland B. Handley
Regional Director

STATE OF DELAWARE

WATER AND AIR RESOURCES COMMISSION

DOVER, DELAWARE 19901

LOREN H. FRYE, CHAIRMAN
HAROLD L. JACOBS
VICE CHAIRMAN
JOHN C. BRYSON
EXECUTIVE DIRECTOR

PHONE 302 734-5711
EXT 470-471

October 10, 1967

Mr. H. F. Michel, Chief
Engineering Division
Department of the Army
Philadelphia District, Corps of Engineers
Custom House - 2D and Chestnut Streets
Philadelphia, Pennsylvania 19106

Dear Mr. Michel:

In reply to your letter to Mr. Bryson requesting information on the pollution in the Broadkill River, the following is presented:

There are three waste sources in the Broadkill River Basin discharging directly into the Broadkill River. Two of them are at Milton, Delaware and one near Lewes, Delaware. The Town of Milton has a primary treatment plant with chlorination facilities. The plant is operating satisfactorily. The Draper Canning Company also at Milton has a year-around canning and freezing operation. The wastes from the cannery are at the present treated in an aerated lagoon, after a good screening. However, the present effluent from the cannery is not satisfactory. The cannery is under orders to provide sufficient treatment to prevent the pollution of the Broadkill River. In accordance with the Commission's orders, the cannery has submitted a report on the control measures to be taken to prevent the pollution of the Broadkill. The additional treatment measures include a large aeration pond with settling facilities for sludge and recirculation. It is anticipated that effluent from the cannery will meet all the requirements of the Water and Air Resources Commission as well as the stream standards set for the Delaware Bay.

The third source of waste is a small clam cannery near Roosevelt Inlet. The cannery has practically no liquid wastes and the solid waste consists of clam bellies, which are disposed into the creek. However, the bellies do not cause any problem beacause they serve as a source of food for the fish. Should the discarded bellies become a problem, the clam factory will be required to provide sufficient treatment.

We anticipate the enhancement of water quality in the Broadkill River to be effective in a period of two years.

If you have any questions in this matter, please feel free to contact us.

Very truly yours,

N. C. Vasuki

N. C. Vasuki, P.E., Director
Water Pollution Control Division

NCV:tc

State of Delaware
DELAWARE GEOLOGICAL SURVEY
University of Delaware
Newark, Delaware
19711

JOHAN J. GROOT, State Geologist
16 Robinson Hall
Phone: 302-738-2568

October 11, 1967

Mr. H. F. Michel
Chief, Engineering Division
U. S. Army Corps of Engineers
Custom House
Second and Chestnut Streets
Philadelphia, Pennsylvania 19106

Dear Mr. Michel:

Thank you for the opportunity to comment on the proposed small beach erosion control project for Broadkill Beach, Delaware. We have no doubt that the Corps of Engineers has investigated this project with its usual thoroughness and are pleased to learn that Broadkill Beach has been found to be eligible and suitable, at least to the stage of the detailed project report. Within the limits of our knowledge of the situation and the details available to us, the plan which you have outlined appears to be very well conceived.

We do hope that in each case of beach erosion control consideration is being given to the fundamental causes of erosion in the framework of natural geologic sediment distribution processes. The suitability and sources of sand to be used for nourishment are also matters of some concern to us and we hope that you will call upon us to provide whatever assistance we may in these areas. Our general concern with geologic processes, sources of materials and effects on natural conditions has been expressed in our letter of April 25, 1967 regarding the proposed erosion control project for Delaware's Atlantic Coast.

We wish to again express our appreciation of your interest in our remarks and offer our resources if they can contribute to your admirable efforts.

Sincerely,

Robert R. Jordan

Robert R. Jordan
Assistant State Geologist

RRJ:mac

State of Delaware
DELAWARE GEOLOGICAL SURVEY
University of Delaware
Newark, Delaware
19711

JOHAN J. GROOT, State Geologist

Tel. 368-0611, Ext. 342, 420

April 25, 1967

Col. W. W. Watkin, Jr.
District Engineer
U. S. Army Corps of Engineers
Custom House
Second and Chestnut Streets
Philadelphia, Pennsylvania 19106

Dear Col. Watkin:

The "Tentative Field Recommendations" of the District Engineer, U. S. Army Corps of Engineer District, Philadelphia, for the improvement of the Delaware coast beaches were publicly presented at a meeting held February 2, 1967 at Rehoboth Beach High School. The Delaware Geological Survey wishes to submit the following comments on the plan on the basis of the small amount of information presently available. The Survey has been concerned with various aspects of the Delaware coast which are influenced by geologic conditions and phenomena, especially in the areas of land-sea interaction, with resulting sand migration, and water supply for private, State, and Federal developments attracted to the shore area.

Upon preliminary examination, the tentative plan offered by the U. S. Army Corps of Engineers appears to be well designed to cope with the protection of the Atlantic Shore from Fenwick Island to Cape Henlopen. The plan relies on the established concept of building an adequate system of beaches, dunes, and structures and maintaining it by artificial nourishment of the beaches and dunes. The engineering of this project is undoubtedly backed by detailed consideration of erosion rates and trends. As the project has a life of 50 years, and as we are all concerned about the long-term development of Delaware, fundamental, relatively slow-acting, geologic processes may be significant.

Wave energy is expended in the transportation of sand on any beach. On the Delaware shore the sand removed is not naturally replaced because of a lack of headlands and sand-carrying streams. In the geologic framework, however, this

process appears to be superimposed on a more fundamental increase in relative sea level, which could be the ultimate source of energy for the erosion of the coast. Rates of erosion must be accurately known in order to counteract them with adequate nourishment. Such rates may be derived from various lines of evidence based on measurements made over the period of a particular study, the historical record of maps and events, and from considerations of the positions and ages of geologic materials identified with a particular environment. Rates derived from the detailed studies of the Corps of Engineers and the reconnaissance studies of the Delaware Geological Survey are in substantial agreement. However, the geologic evidence further suggests a relative increase in sea level at a minimum rate of 1 foot per century for at least 400 years. This is essentially in agreement with the shorter term record of Atlantic Coast tide gauges. The figure appears small, but it may be translated into a lateral migration of the shoreline of at least 100 yards per century.

It is our understanding that the plan now under consideration is based on the assumption of a static sea level. We would suggest that the extrapolated 0.5 foot rise in sea level over the life of the project is significant and may result in the necessity of increased rates of beach nourishment during the later years of the project. A recent paper by M. L. Schwartz, "The Bruun Theory of Sea-Level Rise as a Cause of Shore Erosion" (Journal of Geology, v. 75, p. 76-91, 1967), appears to lend some support to the significance of sea-level influence upon beach erosion.

Beyond this primary point, basic questions concerning the natural sources and destinations of sand in transit on the beach remain unanswered. The possibility exists of gaining an understanding of the entire natural system so that, perhaps, it can be made to work to Man's benefit. We might also question whether the million yards of sand to be used each year for beach nourishment might ultimately come to rest in some undesirable location. Further, it was observed after the March, 1962 storm that there was some coincidence between areas of heavy beach utilization and areas of heavy beach damage. It is inferred that trampling of the dunes and some construction activities create loci for accelerated erosion. It is hoped that the predicted high rates of beach utilization in 50 years have been adequately considered.

In summary, we would urge that the shore improvement plan take into account the possible effects of a changing sea level; that the nature and degree of land usage be considered; and the continuing inquiry into the fundamental causes of the erosion

of Delaware's shoreline be encouraged. These points may be found to be covered when the detailed plan for the protection of the coast is released; however, we wish to make available, for your consideration at this early stage, any observations or findings of the Delaware Geological Survey that may be of value. When requested, we shall be pleased to attempt to supply information concerning the nature and location of sand bodies possibly suitable as sources of beach and dune materials. As development of the protected area will be of major consequence to the water supply situation, and because the removal of large quantities of sand at some localities could also affect water supplies, we will, in any case, wish to coordinate our activities with those of the Corps of Engineers, in order that the planning of our future efforts may be efficiently directed.

Sincerely,

Robert R. Jordan

Robert R. Jordan
Assistant State Geologist

RRJ:mac

cc: Vice President G. M. Worrilow

A. KIRK MEARNS, JR.
SECRETARY

DEPARTMENT OF HIGHWAYS AND TRANSPORTATION

DOVER, DELAWARE 19901

December 23, 1971

Colonel Carroll D. Strider
Department of the Army
Philadelphia District, Corps of Engineers
Custom House - 2D & Chestnut Streets
Philadelphia, Pennsylvania 19106

Dear Colonel Strider:

We appreciate your letter of December 17, bringing to our attention, the scheduled public hearing for January 6 to discuss improvements for the beaches of Broadkill Beach and Lewes, Delaware. I do not believe we have any additional material with which to update previous comments, except to reiterate the concern of the local residents for the deterioration of the beach areas.

We will plan to be represented at the meeting.

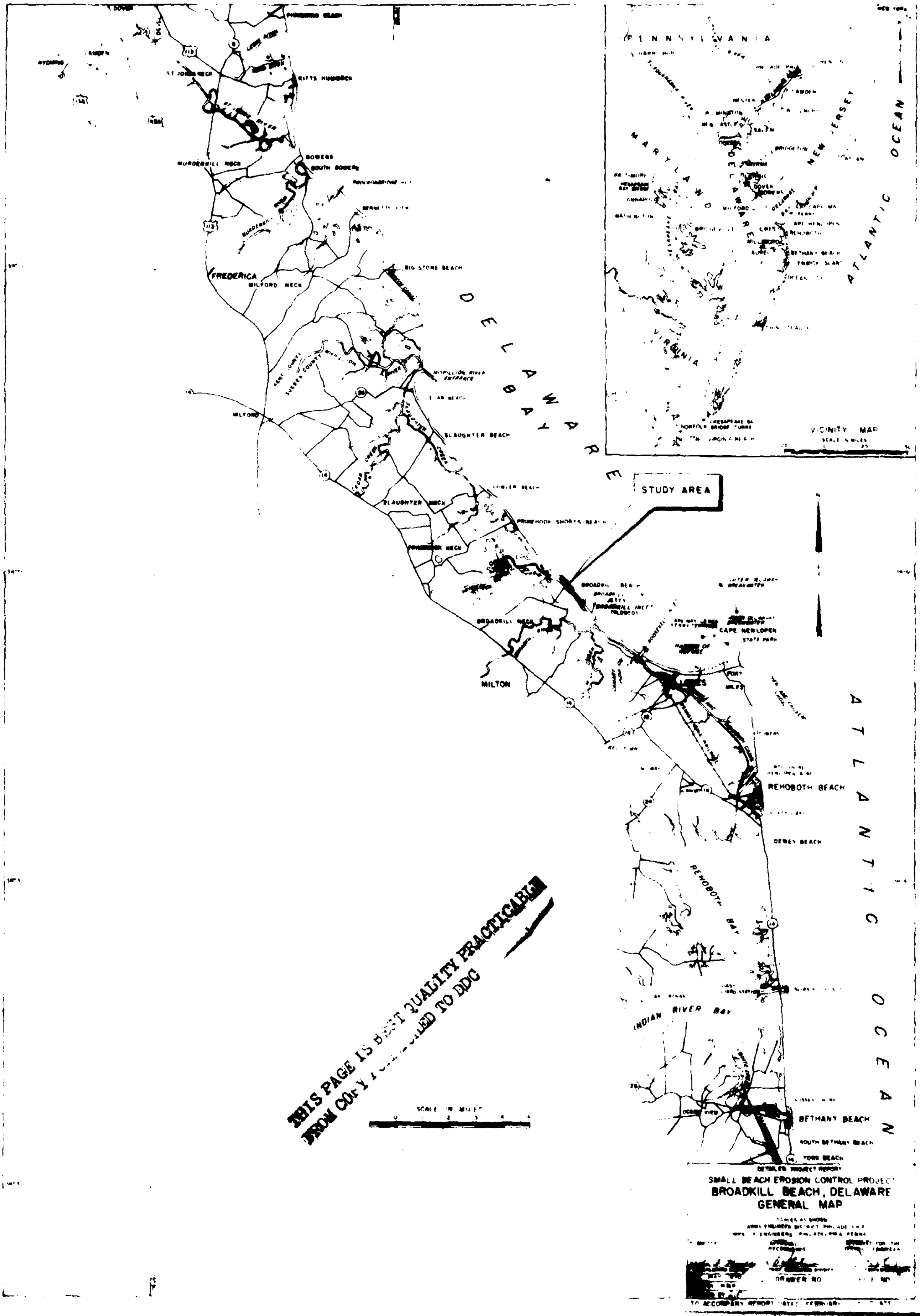
Sincerely,

A. Kirk Mearns, Jr.

A. KIRK MEARNS, JR.

AKM:EAD:ih

CORPS OF ENGINEERS U.S. ARMY



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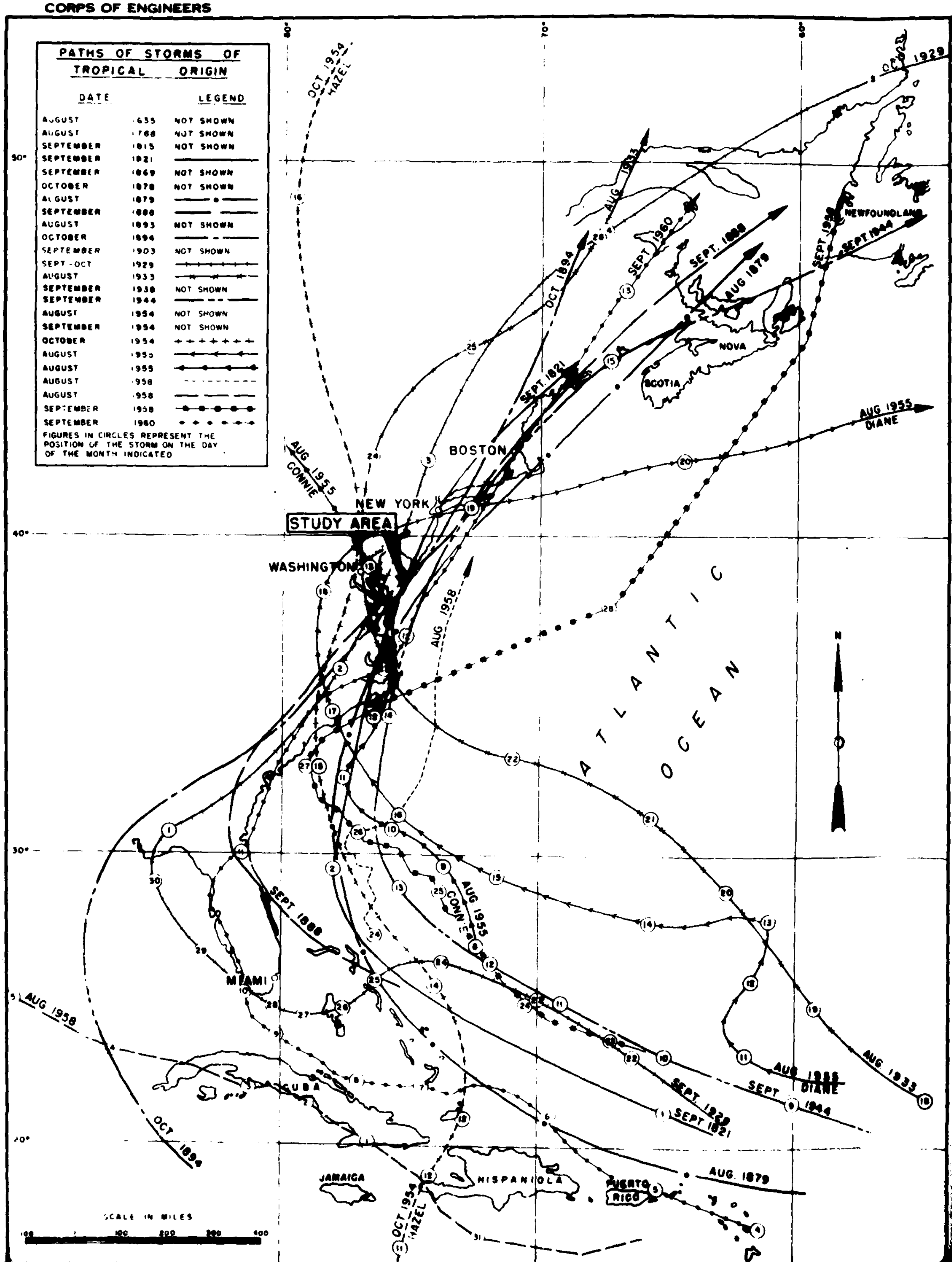
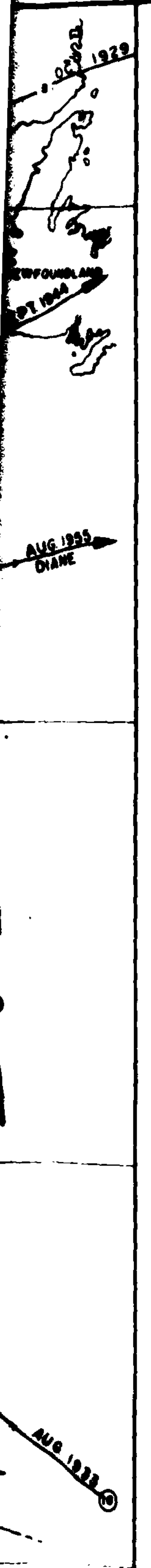
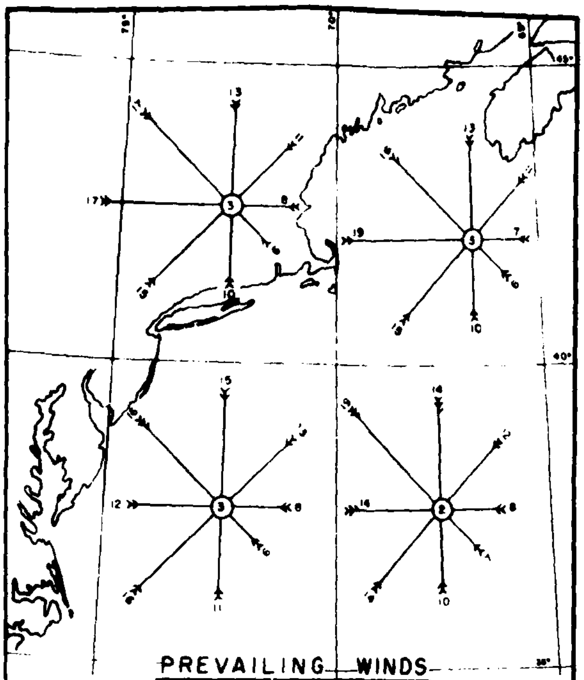


U.S. ARMY

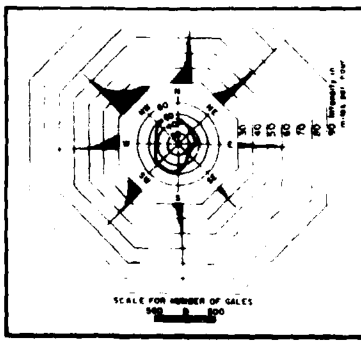




PREVAILING WINDS

WIND ROSES SHOW AVERAGE WINDS FOR 5° SQUARE OVER ENTIRE PERIOD OF RECORD. ARROWS FLY WITH THE WIND. FIGURES AT END OF ARROWS INDICATE PERCENT OF OBSERVATIONS WIND HAS BLOWN FROM THAT DIRECTION. NUMBER OF FEATHERS REPRESENTS AVERAGE FORCE, BEAUFORT SCALE. FIGURE IN CIRCLE REPRESENTS PERCENTAGE OF CALMS, LIGHT AIRS AND VARIABLES.

BASED ON SHIP OBSERVATIONS AS COMPILED BY THE NAVY HYDROGRAPHIC OFFICE FOR 10 YEARS PERIOD, 1932-1942.



WIND DATA

DELAWARE BREAKWATER, DEL.

NOTE:

DATA WERE OBTAINED FROM U.S. WEATHER BUREAU, PHILA., PA. FOR PERIOD 1924-1941.

THE INTENSITY DIAGRAMS REPRESENT WINDS OF GALE FORCE (30 MPH) OR GREATER, AND ARE BASED ON DAILY MAXIMUM 5-MINUTE VALUES. THE INTENSITY OF GALES IS INDICATED BY LENGTH OF LINE, AND WIDTH ALONG BASE SHOWS, TO THE SCALE INDICATED, THE NUMBER OF DAYS DURING THE 18-YEAR PERIOD HAVING WINDS OF A GIVEN INTENSITY RANGE.

THE WIND DURATION DIAGRAM INDICATES THE AVERAGE NUMBER OF DAYS PER YEAR FOR EACH DIRECTION, BASED ON HOURLY WIND RECORDS.

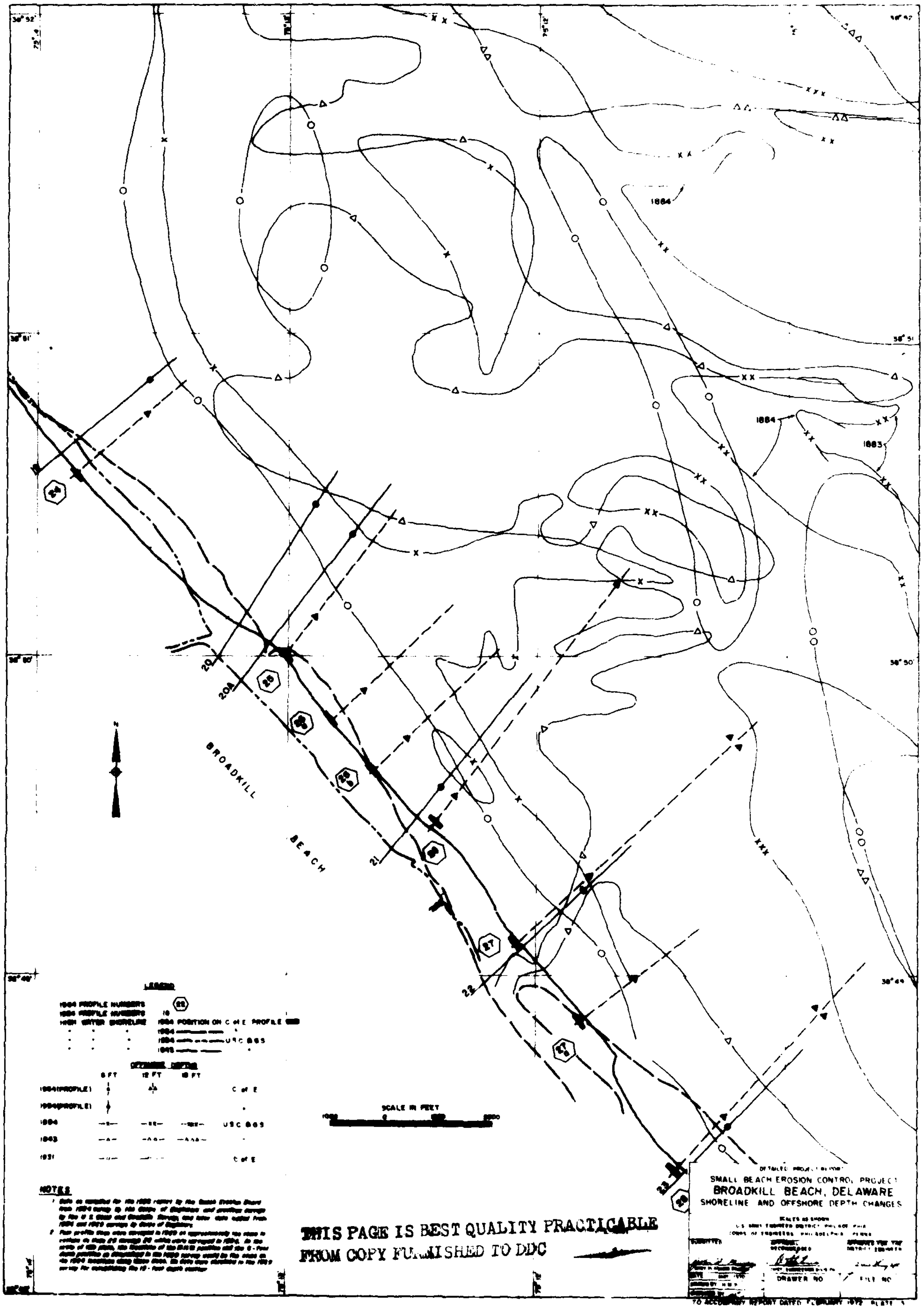
DETAILED PROJECT REPORT
SMALL BEACH EROSION CONTROL PROJECT
BROADKILL BEACH, DELAWARE
STORM & WIND DATA

SCALES AS SHOWN
U.S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS, PHILADELPHIA, PENNA.

SUBMITTED	APPROVAL RECOMMENDED	APPROVED FOR THE DISTRICT ENGINEER
	CHIEF, ENGINEERING DIV	LT COL, CORPS OF ENGINEERS
DATE MAY 1970	DRAWER NO	FILE NO
DRAWN BY R.M.P.		

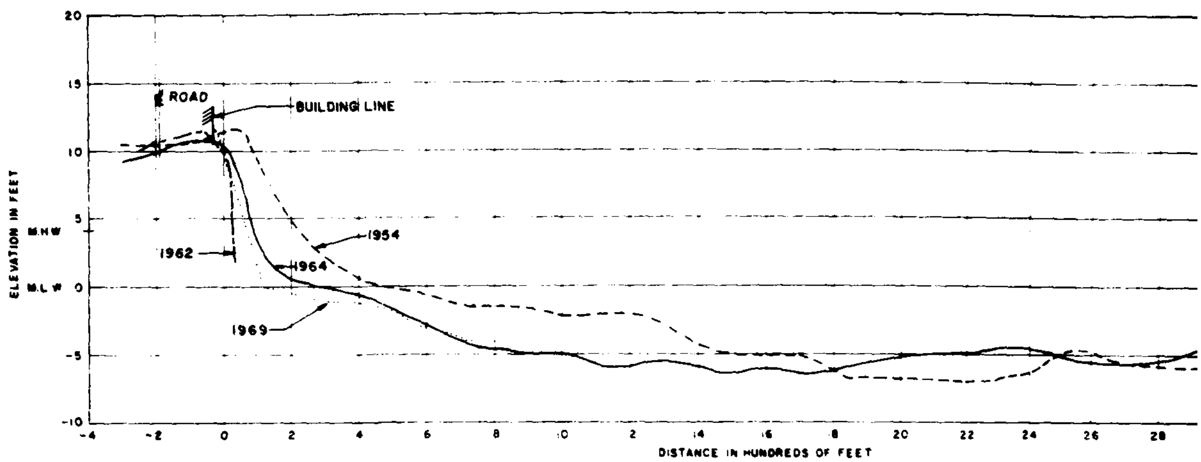
PLATE 2

2

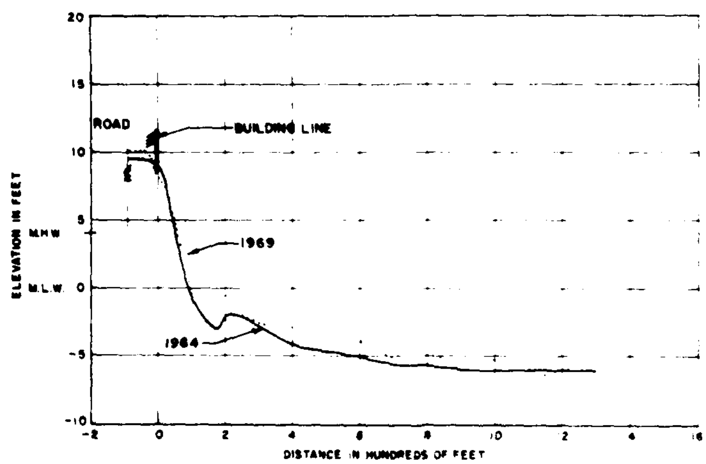


TO ACCOMPANY REPORT DATED FEBRUARY 1972 PLATE 5

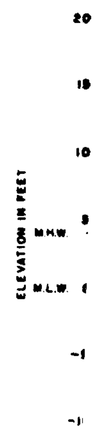
CORPS OF ENGINEERS



LINE 25 - 1964



LINE 25B - 1964



AD-A082 469 ARMY ENGINEER DISTRICT PHILADELPHIA PA F/G 13/2
DETAILED PROJECT REPORT. SMALL BEACH EROSION CONTROL PROJECT. B--ETC(U)
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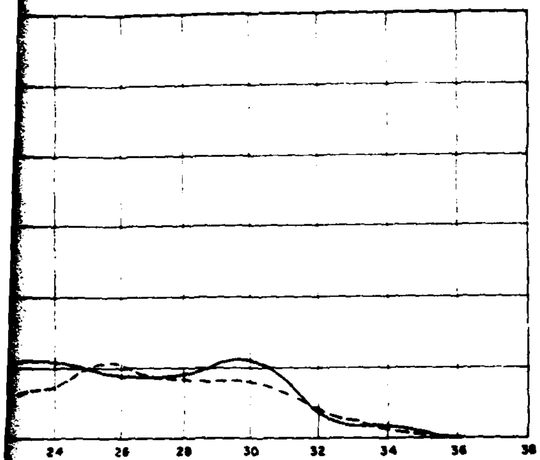
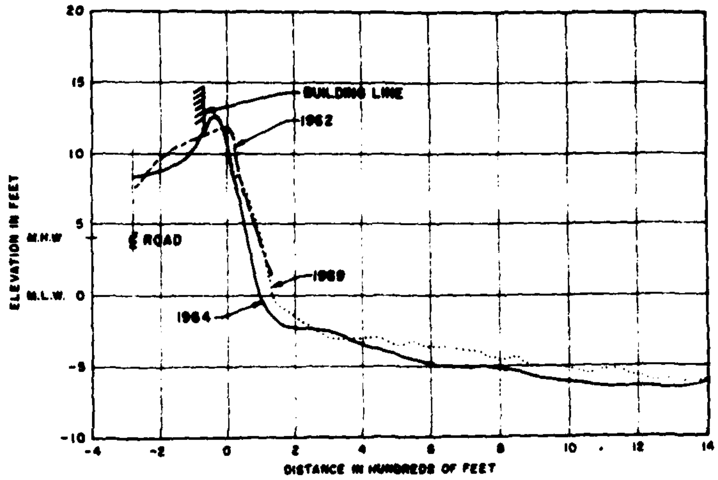
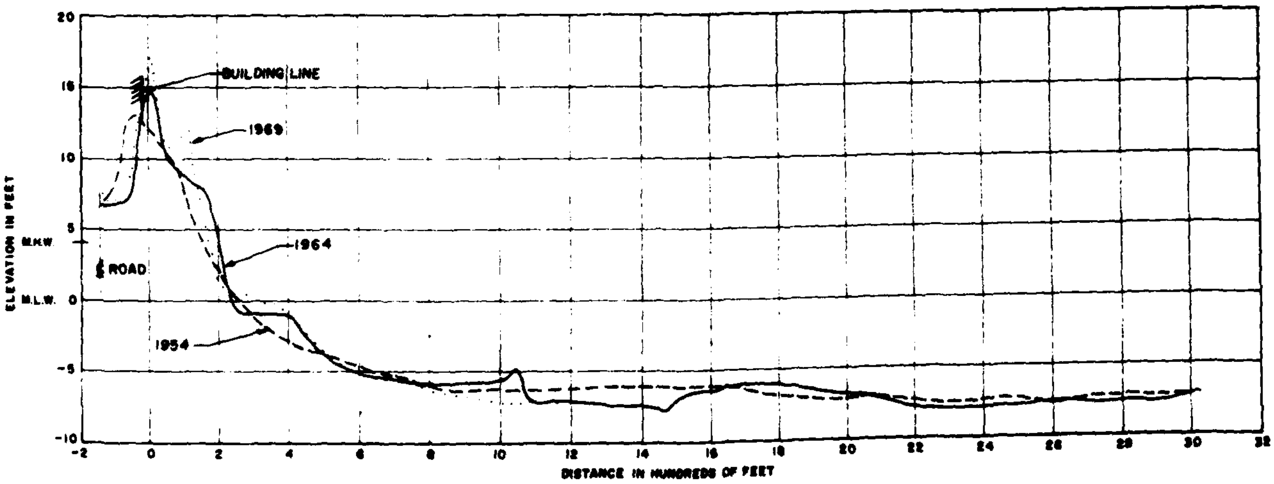
U.S. ARMY





LINE 25A-1964



LINE 26-1964

DETAILED PROJECT REPORT
SMALL BEACH EROSION CONTROL PROJECT
BROADKILL BEACH, DELAWARE
COMPARATIVE PROFILES

SCALES AS SHOWN
U.S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS, PHILADELPHIA, PENNA.

SUBMITTED

DATE: MAY 1970

DRAWING NO.

FILE NO.

2

CORPS OF ENGINEERS